



Integrative data system for monitoring biota and natural habitats in the Israeli Eastern Mediterranean marine environment

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Abstract An integrative data system for monitoring the biota of the Mediterranean waters of Israel as well as selected records from adjacent Levantine basin regions is presented here, aimed at providing data and research tools for long-term bio-geographic and ecological studies and more important, providing background data for assisting governmental regulators to establish educated habitat-oriented environmental policy. The system relies on the geographic information system (GIS) online map-based platform and contains at present the following components: biotic database of ~170,000 recorded sampling events; uniform habitat maps of 63 benthic habitats and 2 pelagic ones, constructed using relevant bathymetric features and biotic community compositions; bathymetric hill-shade map; depth contours; raster depth grid and human interference map. Other informative auxiliary maps are planned to be added (e.g., map of potential pockmark sites, detailed maps of tiny carbonate crust nolls and more). A number of 883 cited documents were listed by us for potential extraction of sampling

efforts, most of them are available to us as PDFs and are available also to the users, excluding copyright-protected ones. Forty-three major projects were depicted in addition to a variety of small studies (e.g., university theses). Thirty-five sampling devices were documented and described, and 3187 species-level identifications were already recorded. In addition, the system provides access to description of sampling devices and pictures of species and seascapes. New data is continuously deposited to the system and the system is flexible, allowing future addition of new types of information. The system site is accessible through the link: <https://experience.arcgis.com/experience/40e86605ff4d4e5096ed2c901fec2a2f>.

Keywords Biotic database · Habitats · Mediterranean Sea · Levantine basin · Geographic information system · Israel

Introduction

The Israeli waters have been intensively used for a variety of anthropogenic purposes: harbor and anchorage facilities, cooling of power stations, desalination plants, treated sewage disposal, gas exploration and production facilities, fisheries, recreation, and military activities. Non-indigenous biota may potentially invade the Israeli waters from the Western Mediterranean and through global ship transport. However, the most striking invasion phenomenon, mainly

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occurring in the continental shelf, is the Lessepsian migration, i.e., an invasion of species of Indo-Pacific bio-geographic origin into the Mediterranean Sea via the Suez Canal (Galil et al., 2018). The intensive anthropogenic disturbance has called for intensive environmental studies and monitoring activities that were aimed at the determination and updating of efficient environmental policy, and also led us to develop the integrative biotic data system presented here.

The 26,000 km² Israeli Mediterranean province, territorial waters and exclusive economic zone (EEZ) with ~190-km coastline, is divided into a continental shelf (<100-m depth), continental slope (between 100 and 1000-m depth) and bathyal basin (1000–2000 m depth), following Harris et al. (2014) division and it is the shallow eastern part of the Levantine basin. The Israeli waters bathymetry and main morphological features were described in Hall et al. (2015), Gvirtzman et al. (2015), and Kanari et al. (2020) and are presented in Fig. 1. Major features of the continental shelf are soft sediment (sand, silt mostly) patched with rocky bottom seafloor outcrops. These rocky patches are either limestone promontory of the Carmel head (Almagor & Garfunkel, 1979) or remnants of aeolianite sandstone ridges (Tsoar, 2000) from the erosional surface of glacial maximum periods (locally named kurkar), buried under the soft sediment of the shelf during interglacial period (e.g., present day) and piercing out of the seafloor in places (Sivan & Porat, 2004). Additional rocky seafloor in the coastal zone are beach rocks and coastal rock outcrops, as well as Vermetid reefs (Rilov et al., 2019; Safriel, 1974). The slope and bathyal basin seabed are comprised of five main morphologies formed by sediment transport processes and salt tectonics: folds, faults, sediment waves, deep-water channels, and sediment fan lobes (Kanari et al., 2020). The upper slope is characterized by canyons in the northern region (Almagor & Hall, 1984), and submarine landslides in its southern part (Katz et al., 2015). Additionally, two large slump complexes, Dor slump and Palmahim disturbance further south, are major features of the slope (Almagor & Garfunkel, 1979 and Fig. 1). The bathyal basin bottom is mainly a large muddy region crossed by northerly bound submarine channels. Two sediment transport mechanisms divide it into two distinct areas: in the south-west and the center of the basin, the Nile derived siliciclastic sediments which are transported directly into the deep basin via confined flows (forming meandering channels and over bank deposits) and

unconfined flows (forming fans and lobes). In the north-east, the slope and basin are fed by erosion products of the Nile outlet that were transported northwards along the continental shelf by seafloor currents of the Levant jet system, and glided down the northern Levant continental slope as turbidity currents (Jaijel et al., 2023; Kanari et al., 2020; Schattner & Lazar, 2016). Both the slope and the shallow part of the bathyal basin are punctuated by isolated carbonate crust rocky patches and are characterized by large areas of cold methane seeps (Eruteya et al., 2018; Ezra, 2017; Herut et al., 2022; Lawal et al., 2022; Marine Ventures International, 2018; Makovsky et al., 2022).

Several comprehensive reviews discussed aspects of environmental monitoring. Lindenmayer and Likens (2010) provided a comprehensive outline of environmental monitoring types and considerations, including socio-economic and personal aspects. They determined three motivations for monitoring and the presented integrative system already responded to all of them, namely, curiosity (Lubinevsky et al., 2022, 2023), trend detecting (Lubinevsky et al., 2019) and scientific question-driven (Hyams-Kaphzan et al., 2018; Lubinevsky et al., 2017). Danovaro et al. (2016) presented new monitoring methodologies. One of them which is relevant to the presented integrative system is molecular taxonomy. Besides megafaunal taxonomy, which is relatively known, the task of identifying macro- and meiofauna, fungi, and eukaryotic Protista is very difficult and slow, definitely if regular routine monitoring is considered. The reasons are the well-acknowledged shortage of expert taxonomists for all the relevant groups that are routinely available, but also poor taxonomy knowledge for some groups. The suggested solution, on global scale, for that difficulty was the utilization of species-specific DNA sequences as taxonomy markers through the barcoding (Hebert et al., 2003) and metabarcoding methodologies (Gielings et al., 2021). Molecular taxonomy methods were already fully adopted for bacteria (Bolyen et al., 2019). Metabarcoding was already accomplished by two of the co-authors of this article for meiofauna, using a 18S-V4 barcode, and their approach was described in Harbuzov et al. (2022). Bean et al. (2017) outlined the UK monitoring system and the integration of its components through modeling including future perspectives. Environmental models can be applied by the integrative system consumers using the system data. However, the approach presented here for habitat delimitation relied only on actual observations with no model-based predictions.

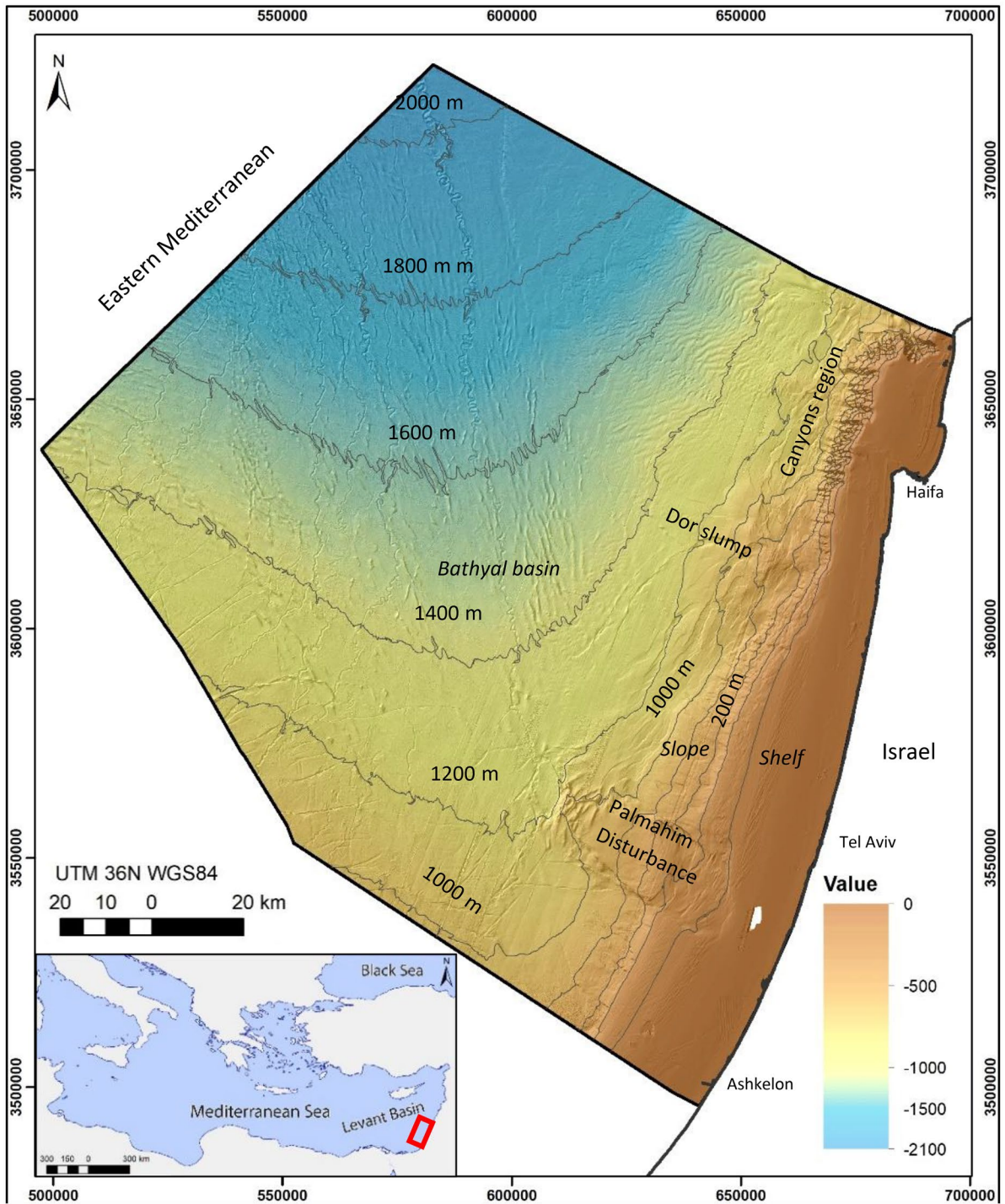


Fig. 1 Hill-shade map of the Israeli waters of the Mediterranean (Kanari et al., 2020). Red rectangle in the inset—the study area

Monitoring temporal and spatial presence and abundance of species in natural environments is a major tool for detecting environmental changes, assuming that the biotic composition, its abundance, and its species diversity indices are affected by moderate as well as by acute environmental changes and can serve also for long-term bio-geographic and ecological studies. Three terms and their accompanied working assumptions are important in the context of biotic monitoring: (1) the species is the basic biotic measurement unit being relatively uniformly affected by its biotic and abiotic surroundings. Hence, it is desirable to identify individuals to species-level. (2) The biotic community characteristics, namely the list of species in an identified space and/or time, their relative quantities (e.g., density, coverage, biomass), and their species diversities, are the monitoring indices. Changes of biotic community characteristics can indicate environmental disturbances. (3) Uniform habitat (termed “habitat” throughout the article) is an environmental realm hosting relatively uniform biotic community and characterized by both its biotic community characteristics and the surrounding environmental conditions. Each habitat is considered by us a target for specific environmental policy and environmental regulation.

Consequently, the suggested integrative system is aimed at identification of uniform habitats in the Mediterranean marine province of Israel, including characterization of their biotic communities, with the desired aim of species-level identification. It would enable researchers and regulators an easy access to information sources and to comprehensive,

clearly visualized, and easily extractable data, permitting the performance of ecological analyses, assisting educated regulation, and provide long-term organizational memory. The target organizations are governmental agencies and the scientific community. The system is an ongoing venture, continuously updated with new uploaded data and it is considered by us at present sufficiently informative for exposure to the public.

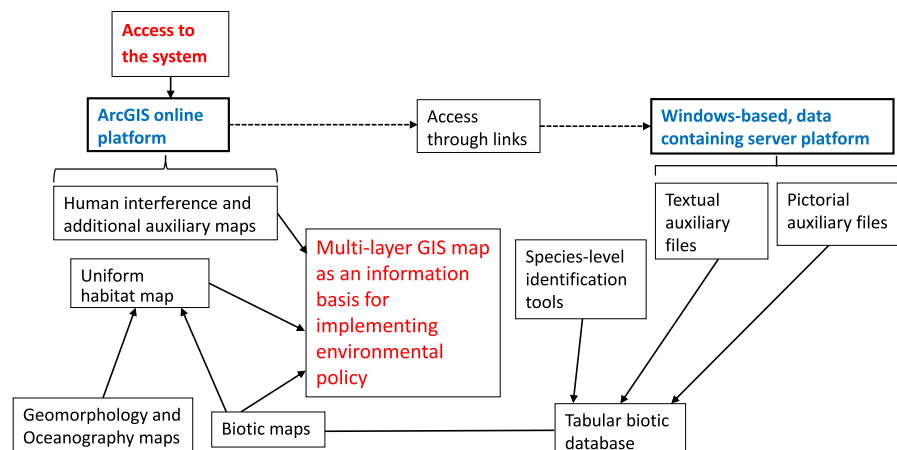
Once published, comprehensive European and global biological databases would be approached mutually examining cooperation, coordination, and data integration with appropriate and positively responded databases, further broadening the exposure.

Materials and methods

General

The integrative system is schematically described in Fig. 2. It technically relies on two pillars: the major one is the global geographic information system (GIS) and its ArcGIS online platform (ESRI, USA) <https://experience.arcgis.com/experience/40e86605ff4d4e5096ed2c901fec2a2f>. The auxiliary site is the Windows server 2012R2 which stores a variety of textual and pictorial documents. The access to both platforms of the system is allowed through the ArcGIS online site. Although based on a global platform, the system is focused on the Mediterranean waters of Israel, but important data from neighboring regions (e.g., the Suez Canal and other selected eastern

Fig. 2 Schematic presentation of the integrative biotic monitoring system



Mediterranean regions) was deposited when considered beneficial.

The GIS platform (Fig. 2) is a multi-layered map. A tabular attribute table underly each of the map layers, describing each of its components, and is part of the information provided by each map layer.

It has to be noted that the presented system like other similar ones worldwide is a live entity, continuously improved and some of our near future plans were described throughout this article. The general shape of the monitoring system main screen and its substantial components are detailed in Fig. 3.

Main screen of the integrative system site

The main screen of the integrative system GIS online-related site (Fig. 3) is divided into three zones: the upper right GIS map, the lower right attribute table tabs, and the left side pane of selection tools.

The site is self-explanatory and hovering the pointer over an icon provides short explanation. Resetting the map to initial presentation is done by clicking the icon at the lower right corner of the attribute table pane and selected records from the attribute tables can be downloaded using the arrow

icon at the lower left side of the attribute table (Fig. 3). Details of the main screen are presented in Fig. 4. Drop-down menu at the upper left side enables spatial selection of sampled areas (Fig. 4A). Icons in the upper right side of the map are aimed at presentation of map layers (Fig. 4B, C). Mining of data from anywhere on the map pane is available by left click on the desired point (Fig. 4D). The left side selection pane contains selectable fields of the attribute tables equipped with drop-down lists of all unique items in each field, which could be selected across the points, lines, and polygon layers by left click on them. Additional selection options are described in the “Biotic database” section below.

Biotic database

The goal of the biotic database is to record all historical biotic samplings done along the Israeli coast of the Mediterranean. It is kept updated by continuous deposition of new sampling data, done by the integrative system team at the Israel Oceanographic and Limnological Research (IOLR) through a quality assurance process. The sources for construction of the biotic database are articles, reports, dissertations,

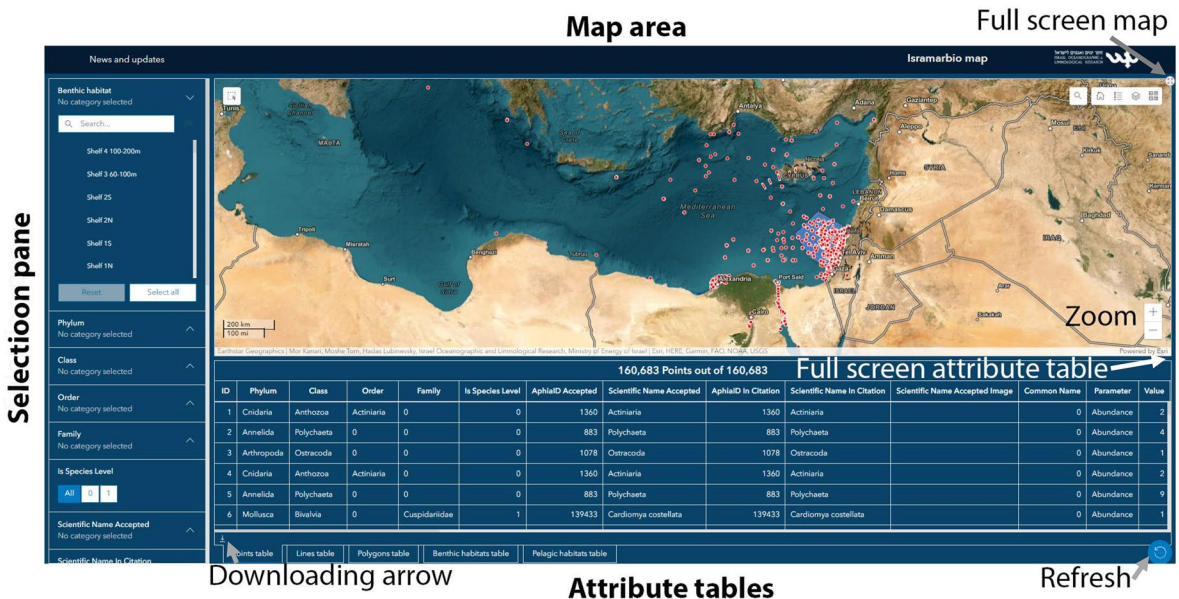
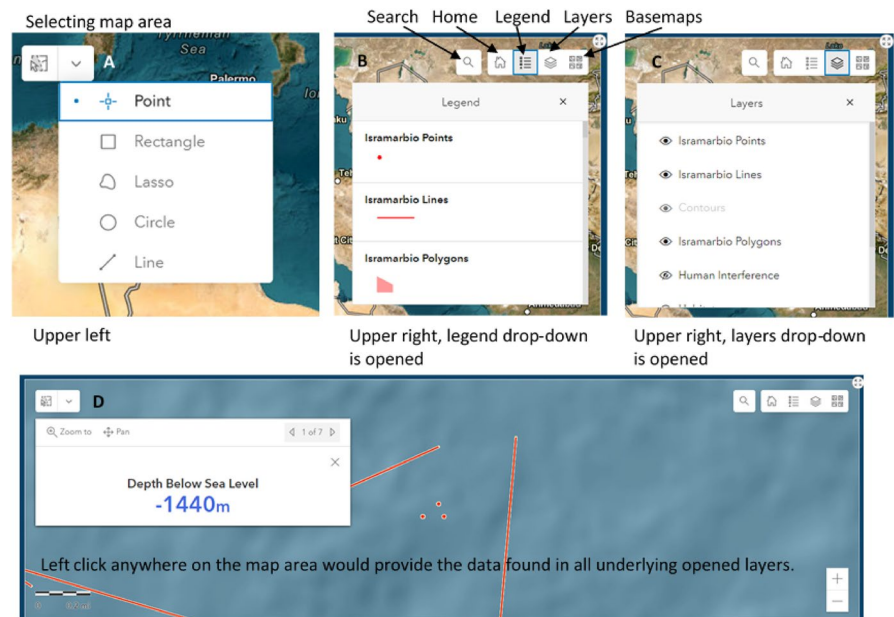


Fig. 3 General view of the GIS-online main screen. Map area (top right), attribute tables and tabs (lower right), and selection pane (left). The gray arrows point toward operational icons which perform the depicted actions. The main screen is

preceded by a disclaimer and general description. Another text box, news and updates (right upper part of the map area), can be opened by left click

Fig. 4 Details of the GIS-online main screen. **A** Options for selection of map area and its data contents, **B** layers' legend, **C** layer selection, and **D** mining of data by left click from anywhere on map pane



and other documents. Unpublished available information provided by researchers and monitoring agencies before their documentation could also be deposited. Unpublished records may be temporarily unavailable to the public to protect researcher's rights.

The biotic database is composed of three GIS layers with their attribute tables. On the map, points or lines mark sampling locations performed in one point (e.g., grab samplings) or along a determined line (e.g., net tows), respectively. Each polygon in the polygon layer designate samples with only general description of the sampling region (e.g., isobath-delimited distribution range). A row in each of the three attribute tables is designated here a record containing specific taxon with its accompanied attributes (Table 1). These attributes are divided into taxonomy and taxon description, quantitative sampling details, administration and documentation, coordinates and timing of sampling, size sorting of the sample, and additional miscellaneous information which enable the selection of specific records according to this variety of characters.

Quality assurance is part of the deposition procedure. It includes checking species name spelling and taxonomy, guided by the WoRMS database (Ahyong et al., 2023) as reference, uniform designation of the various items in the attributed fields (e.g., uniform names to each project, marine region, device) and

uniform units (e.g., decimal degrees for coordinates, cm for sub-bottom layers, meters for depth, square meter for area). The units are depicted in the headers of the field columns.

The accuracy of deposited data is the responsibility of the data sources, directly or through deposited contents of documents, similar to the rules of the nucleic acid and protein sequence public databases. The data provided for each record can assist the user to subjectively evaluate its quality. Examples are the trust in identification in relation to the identifier name, identification level, and method of identification (species level or higher, molecular or morphological), examination of the original document looking for more detailed description of the study and more.

The structure of the system is modular and more layers and tabular data could be added, connected or not to already deposited data. Selection of records can be cumulatively accomplished through both geographic delimitation of a perimeter (Fig. 4A) and selection of fields and items in the selection pane (Fig. 3) accompanied by automatic zoom-in of the map to the area which contains the selected records and by attribute tables which contain only the selected items. The selected attribute tables can be exported as Excel-like tables by the downloading arrow (Fig. 3). Highlighting a row in an attribute table will zoom-in the map area to the temporarily blanking highlighted

Table 1 The “points,” “lines,” and “polygons” table tabs are located in the lower left side of the main screen. Each row is an attribute characterizing uniquely sampled taxon and is termed a record. Characters in red are links to PDF documents located in the Windows-based server

Group	Character	Comment
Taxonomy and taxon description	Phylum, Class, Order, Family	Taxonomy in four levels
	Is_Species_Level	Species-level identification (1 or 0)
	Scientific_Name_Accepted	Present accepted nomenclature and the one depicted in the relevant citation, respectively. WoRMS database (Ahyong et al., 2023) is our reference for accepted scientific names
	Scientific_Name_In_Citation	Accession numbers to WoRMS database
Quantitative details	AphiaID_Accepted	Additional taxon’s attributes
	AphiaID_In_citation	Barcode that was used for molecular identification and the primers that were used for its amplification from a DNA extract
	Common_Name, Scientific_Name_Accepted_Image	Description of value type
	Barcode_18SV4, Forward primer 18SV4, Reverse primer 18SV4	Number describing the quantity of sampled items
Administration and documentation	Parameter	Actual sampling dimensions
	Value	The unit of the sampling dimension
	Sampling_Effort	Sampling device description
	Sampling_Effort_Unit	The person in charge of the sampling effort
Location and timing of sampling	Device, Device_PDF_Document	Article, report, dissertation, etc
	Project_Name, Citation, Citation_PDF, Citation Full Reference, Institution_Name, Marine_Region	Is it a summary of previously reported results or an original record
	Responsible_Scientist	Is this record available for public distribution, alternatives are public or database
	Type_of_citation	Geographic site and date and time of sampling. The line coordinates delimit a line and the polygon layer delimit boundaries of distribution when an exact sampling location does not exist
Size sorting data	Primary_or_secondary	Depth of sampling determines the bottom depth and the actual sampling depth along the water column
	Availability	Location of benthic sample below bottom surface (for benthic samples)
	For point samples: Lat, Long, Time_start, Time_end; For line samples: Lat_start, Long_start, Lat_end, Long_end and for polygons: the sampled area	Station name and ID
	Min_Depth, Max_Depth, min_Bottom_depth, max_Bottom_depth	Identification methods alternatives are morphological or molecular at present
Processing, bio-geographic, life cycle, and general information	Min_SubDepth, Max_SubDepth	
	Station_Name, Station_ID	
	Above_Fraction_Size, Under_Fraction_Size	
	Identified_By, Identification_Method, Life_Stage, Sex, Bio-Geographic_origin, Comment, Comment1	

sample. However, it is not a selection tool for exporting records.

Habitat maps

A major component of the integrative system are the benthic and pelagic habitat maps. A habitat was defined in the “Introduction” above as an environmental realm hosting relatively uniform biotic community and characterized by both its biotic community structure and the surrounding environmental conditions. Detailed description of each habitat is found in the attribute table of the habitat GIS layer (Table 2) which include several types of habitat characters: habitat designation, sources of delimitation information, geomorphological characters, and regulation-related parameters. Records which were sampled within a habitat can be selected through the appropriate box of the selection pane.

Sampling of biota in the Israeli waters of the Mediterranean is not complete in terms of spatial and temporal coverage and practically will never be. Hard substrates, namely rocky seafloor and carbonate crusts, were assumed to host clearly different biota in comparison to their surrounding sediment whether sampled or not. Hence, rocky substrate habitats were identified by the typical response of the bottom to acoustic signals, although biotic information was not always available. Full multibeam bathymetry coverage of the Israeli waters and its derived analyses—multibeam backscatter intensity and bathymetric slope maps (Kanari et al., 2020)—were the major tools for delineation of rocky bottoms. Aerial photography was used to delineate rocks in shallow coastal sites. Visual observation by scuba diving or by cameras mounted on remote operated vehicles

(ROVs) assisted the verification of multibeam data analyses, as well as the identification of smaller rocky knolls and their biota (Ezra, 2017; Herut et al., 2022; Makovsky et al., 2016; Marine Ventures International, 2018; Rubin-Blum et al., 2014a, b, c, d). Sub-bottom profiles were obtained by Knudsen Chirp 3260, working at 3.5 kHz and were used to detect and map rock covered by thin layer of sediment in some of the aeolianite rock outcrop ridges (kurkar). Recently, an autonomous underwater vehicle (AUV) equipped with a synthetic aperture sonar (SAS) imaging system (Makovsky et al., 2021) assisted also the identification of deep-sea carbonate crusts. Available biotic data of rocky regions was deposited in the biotic attribute tables.

Sedimentary bottom was generally identified from sedimentological literature and by the multibeam bathymetry. However, delimitation of sedimentary habitats was accomplished by arbitrary division of the gradually changing sediment followed by comparing biotic community compositions and demonstrating significant differences among sampled areas. Examples for such analyses are found in Galil and Lewinshon (1981), Tom and Galil (1991), Lubinevsky et al. (2017, 2019), and Hyams-Kaphzan et al. (2018).

Several kurkar ridges and deep-sea habitats are complex, composed of isolated but densely distributed rocky knolls surrounded by soft sediment. In the aeolianite ridges, it was a result of partial coverage of the rocky bottom by soft sediment and in the deep sea it was probably due to the pattern of methane seepage, indirectly responsible for the deposition of the carbonate crusts. In those cases, for the sake of simplicity, dense knoll fields were distinguished by an encircling perimeter containing the knolls and their surroundings, and the exact locations of the knolls are planned to be presented as a separate auxiliary GIS layer.

Pelagic habitat mapping is in its infancy. At present, it contains two, 2-dimensional epi-pelagic habitats of the two most common cetaceans along the Israeli waters, *Tursiops truncatus* and *Delphinus delphis*.

Auxiliary maps

Several layers which are considered by us beneficial for environmental policy-related decisions or provide more detailed information for specific habitats are also available or planned to be available in the

Table 2 Characters of each unique habitat

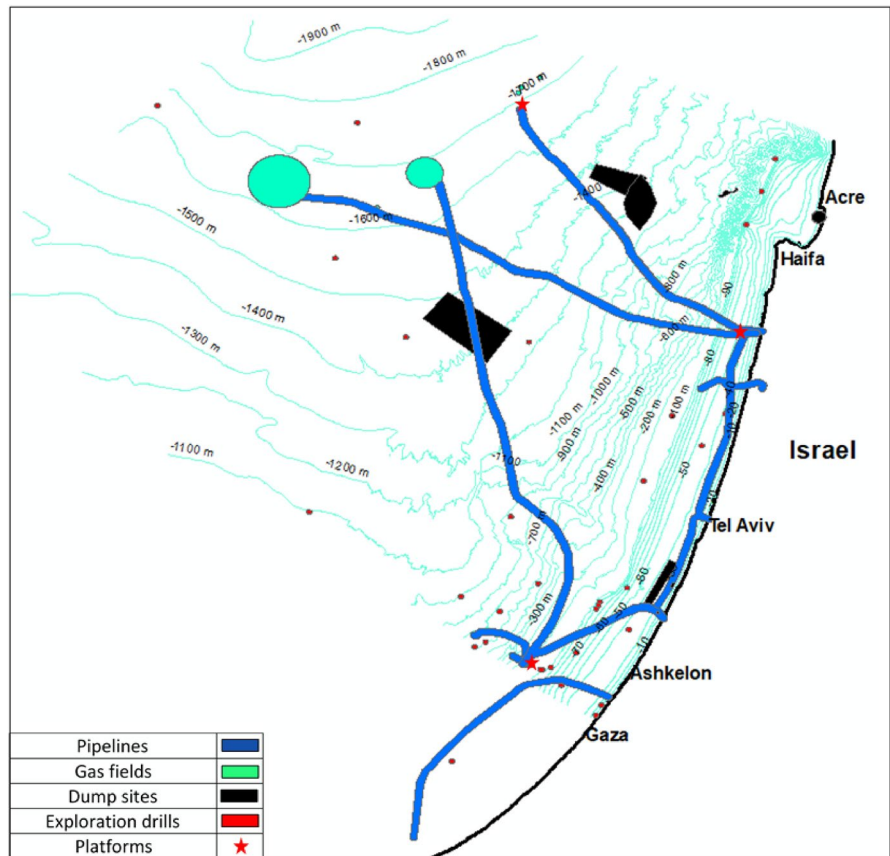
Group	Character
Habitat designation	Habitat ID
	Habitat name
	Habitat label
Sources of delimitation information	Habitat source
Geomorphological characters	Province
	Substrate
Regulation-related parameters	Vulnerability to damage
	Habitat area

integrative system. They were constructed or will be constructed using a variety of tools and methodologies, including analysis of multibeam bathymetry and backscatter data for identification of seafloor complex morphologies; interpretation of AUV mounted SAS (synthetic aperture sonar) images of the seafloor to identify pockmarks, gas seeps, and carbonate crusts; ROV surveys for visual inspection and identification; and analysis of 3D seismic data to identify seafloor geological features like pockmarks (Lawal et al., 2022). The presently available layers are hillshade bottom map (Fig. 1) and a map which describe the already present human interference in the Israeli waters of the Mediterranean which contains active and inactive gas industry installations and dumping and drainage sites (Fig. 5). General service layers are depth contours and raster depth grid.

Species-level identification

The planned introduction of molecular taxonomy to our integrative system led us to add fields related to molecular taxonomy data deposition to our “points,” “lines,” and “polygons” tables (Table 1). Metabarcoding was already accomplished by our group at the IOLR using a 18S-V4 barcode and its methodology was described in Harbuzov et al. (2022). Consequently, non-binary species names relying on barcode data would be allowed in the “Scientific_Name_Accepted” and “Scientific_Name_In_Citation” fields. Other fields which present the species-specific barcodes and the primers used for their PCR amplification were already introduced to the records attribute tables. Fields for other barcodes and PCR primers would be introduced as required.

Fig. 5 Human interference in the Israeli waters of the Mediterranean



Results and discussion

The integrative monitoring system site and its contents can be accessed through the link: <https://experience.arcgis.com/experience/40e86605ff4d4e5096ed2c901fec2a2f> and it is actually the resulted product of this study. The data content of the system did not reach our goal of depositing all historical records yet, and approaching this goal would depend on continuous data deposition of already reported, still not deposited data as well as uploading of new data, by the system's team at the IOLR. However, a substantial amount of data and information is already there, and Israeli regulators from the relevant ministries (ministry for protection of the environment and its affiliated nature and parks authority as well as the ministry of energy) and other agencies as well as researchers can enter the site, assisted by the link and guidelines presented here, to obtain data relevant to their field of interest. Surfing through the integrative system site is easy and self-explanatory. At present, around 170,000 records are present in the biotic attribute tables, and the habitat map includes 63 benthic habitats and 2 pelagic ones. The deposited data in the biotic attribute tables were mined from a library of documents, in a variety of languages including Hebrew—some of them are available as PDF documents. The Hebrew documents data is available to the international community only through this database,

unless published also in a more internationally acknowledged language. Data from substantial part of the 883 available documents were already extracted to the biotic attribute tables. Forty-three major projects were depicted in addition to a variety of small studies (e.g., university theses). Thirty-five sampling devices were documented and described, and 3187 species-level identifications were already recorded. The framework for deposition of species figures and seascapes is ready; deposition of species figures was initiated and is planned to be broadened. Also planned is the deposition of species-specific molecular barcodes. The citation of documents from which data was already deposited is found in the biotic attribute tables. When permitted, their PDF is also available. Access to the citation list of all our existing document library is under construction. Being an environmental venture, the presented system is related to socio-economic issues and suggested to be a regulation-assisting tool. Following Lindenmayer and Likens (2010), the maintenance of such system should not be a time-limited project but a continuous effort supported by governmental agencies and it is highly recommended by us to be better and faster updated, assisted by finance from the relevant Israeli governmental bodies, which are actually, the initiators of its construction.

Several examples of data selections performed for already published studies are described in Table 3.

Table 3 Examples of record selections for specific studies

Publication	Attribute table	Selected fields	Selected items	Aim of the study
Lubinevsky et al. (2017)	Points	Project_Name Time_start and Time_end Phylum	Deep sea national monitoring 2013–2013 Excluding Foraminifera	Deep sea macrofaunal communities
Hyams-Kaphzan et al. (2018)	Points	Project_Name Time_start and Time_end Phylum	Deep sea national monitoring 2013–2013 Foraminifera	Deep sea foraminifera communities
Lubinevsky et al. (2019)	Points	Project_Name Time_start and Time_end Station_Name	National Monitoring Program of Israel's Mediterranean coastal waters 2005–2016 Excluding H71*, HB*, HS*, Z2*	Multi-annual monitoring of sandy shelf macrofauna
Lubinevsky et al. (2022)	Points, lines, polygons	Order Is_Species_Level	Tanaidacea 1	Tanaidacea faunistics
Lubinevsky et al. (2023)	Points, lines, polygons	Order	Cumacea	Cumacea faunistics

As already stated, the species is our basic ecological measurement unit, being an entity that fairly uniformly responds to changes in the ambient conditions. As already detailed above, the accurate species-level identification of most of the taxonomic groups which inhabit the Israeli waters is difficult. The introduction of molecular tools and metabarcoding procedures (Danovaro et al., 2016; Harbuzov et al., 2022) and the ability to integrate them into the biotic attribute tables would provide better accuracy of species-compatible identification.

An important part of the system is delimitation of habitats. Rocky habitats as predictors of specific rock-inhabiting biota were elucidated using geo-morphological methods. The division of soft substrate habitats is more difficult due to the gradual change of the substrate physical properties. However, it is clear that, for example, the biota of the shallow shelf is dramatically different from that of the shelf-slope boundary although both belong to the same continuous sedimentary province (Galil & Lewinsohn, 1981; Tom & Galil, 1991). Therefore, we arbitrarily divided the soft bottom gradually changing habitats, especially in the continental shelf, allowing more educated regulation through dealing with more uniform habitats. In addition, biotic fractions including small unicellular organisms, meiofauna, macrofauna, and motile megafauna (Danovaro et al., 2010) should have different weights regarding habitat definition and the more stationary, less motile, smaller, and short-lived species should have more weight when setting habitat boundaries.

The integrative system does not intensively deal with regulative issues, such as determination or indexing habitat vulnerabilities and recommendation on potential establishment of marine protected areas and nature reserves, although a 1 to 4 rough vulnerability scale was temporarily determined in the attribute table of the habitat layers due to practical request of government regulators. Our opinion is that rigid regulation based on rated legally bound arbitrary scale is not recommended, as natural situation is complex and habitat and biotic community responses to disturbances are variable. Therefore, case-specific, more flexible implemented approach guided by several general rules would be more beneficial, modified if required in view of new monitoring results. Regulation has to be divided into two types: rigid determination of protected areas and nature reserves and “soft” and flexible determination of percentage of allowed anthropogenic interference for less sensitive habitats. This percentage should take into consideration the size of the habitat

and its type. The size of each habitat is depicted in the habitat attribute table. Regarding types, rocky bottoms have to be considered more vulnerable than soft substrate ones. Sharp bottom relief of hard substrate has to be considered more sensitive as it is more heterogeneous and potentially more diverse. Sharp relief on soft substrate would be considered less stable, subject to slumping down of sediment and horizon mixing, assumed to contain specific biotic composition and deserves conservation attention.

Connectivity of different habitats is important, but less known and, hence, less predictable. The life cycle and biology of a variety of marine species may involve several habitats. Planktonic larvae of benthic species, confined breeding grounds of widely distributed adults, food sources transported from outside the habitat of inhabitation, motile species which inhabit several habitats, and more. A partial cure to that shortage of knowledge may be the establishment of protected areas which contain more than one habitat and also the already mentioned recommendation of leaving a reasonable percentage of each of the habitats untouched.

Biotic data to the integrative system is provided by scientific research but also by government-initiated regular sampling programs. Basic consideration for designing biotic monitoring program in Israel and the Levantine basin is the poor primary productivity (Berman-Frank & Rahav, 2012; Moore et al., 2013; Siokou-Frangou et al., 2010) and the consequent low biotic density.

The already demonstrated sensitive, vulnerable habitats within the Israeli waters are the shelf rocky habitats down to 130-m depth and the Palmahim slump regions which contain methane and brine seeps and consequent isolated carbonate crust knolls (habitats 11, 12, and 63; see habitat layer on the system site) (Herut et al., 2022; Makovsky et al., 2021; 2022). Suspected, not sufficiently studied regions are the northern slope canyon-region and the Dor slump. As mentioned above, it is evident that a percentage of a variety of soft substrate habitats have to be conserved or protected as well, by limiting the percentage of human interference. With the assistance of the human interference GIS layer (Fig. 5), the percentage anthropogenic utilization could be evaluated and monitored.

Environmental interrelationships include biological, chemical, and physical factors and relating this

biotic database to the IOLR oceanographic database ISRAMAR <https://isramar.ocean.org.il/isramar2009/> would be beneficial and is planned.

Last but not the least, potential cooperation with global and European biotic databases including data integration is welcomed by us and considered mutually beneficial for both sides, exposing our data to broader audience and providing otherwise unavailable East Mediterranean biotic data to European and global databases. Once exposed to the public through this publication, the obvious candidate for cooperation request with our integrative system is the biological part of the European Marine Observation and Data Network (EMODnet) and if positively responded, integration of our data would be discussed and realized. The two databases are very similar, based on GIS platform, containing both tabular and map-based presentation of data and no serious obstacle to data integration is anticipated. Once done, automatic integration to the Ocean Biodiversity Information System (OBIS) managed by UNESCO would be realized through its data sharing with EMODnet-EurOBIS project.

Conclusions

1. An integrative, public, easily accessible database is presented here, providing long-term organizational and national marine environmental memory and aimed at assisting researchers and regulatory agencies.
2. The data is deposited into a uniform table pattern. However, appropriate comparisons among records require selection of similar and comparable record types in relation to quantifiable results, sampling methodologies, and functional and size groups of sampled biotas.
3. The system is an ongoing venture, continuously updated but already includes a substantial body of data.

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Author contribution All three participants joined in planning the integrative system site and writing of the manuscript, led by Moshe Tom. Biotic data deposition was done by Moshe Tom and Hadas Lubinevsky. The biotic, habitat, and auxiliary maps were constructed by Moshe Tom (biotic maps) and Mor Kanari (habitat and auxiliary maps).

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Data availability The article presents a biotic database which is publicly available through the link:<https://experience.arcgis.com/experience/40e86605ff4d4e5096ed2c901fec2a2fexcluding> documents which are under copyright protection. Potentially, submitted but still unpublished data will be temporarily publicly unavailable upon the request of the submitting researchers.

Declarations

Competing interests The authors declare no competing interests.

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