Developing species information systems: the European Register of Marine Species (ERMS)

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What use are species lists?

Species are the most practical and widely applicable measure of biodiversity. They are the common currency for marine biodiversity research and management, and the only measure of biodiversity with a well-established standardized code of nomenclature. Species names (taxonomy) are thus at the foundation of quality control in biological studies.

The presence of a species can indicate the habitats present, environmental quality, and state of knowledge of biodiversity (e.g. rates of discovery, extinctions, range extensions). The relative richness of species in comparable samples can be a good indicator of environmental health.

The most important aspect of biodiversity is species composition (i.e. lists). From checklists of species taken over time (i.e. censuses) the rates of immigration (colonization), emigration, extinction (decolonization), and turnover of species in a community can be measured and modelled. These dynamics measure the stability of biodiversity in ecosystems. Changes in this ecological balance, whether natural or human in origin, may have catastrophic effects on natural resources of importance to mankind (e.g. fisheries, nutrient cycles, algal blooms).

Lists of species, such as provided by The European Register of Marine Species (ERMS), are only the starting point for marine biodiversity management and research. These lists provide a single nomenclature for species, which will generate further research to clarify anomalies. Furthermore, they form the basis for more elaborate species databases, with more synonyms, and data on species distribution, ecology, conservation importance, economic importance, and other information. An added benefit can be that the cooperation amongst scientists in producing the lists increases communication and interest in the management and use of taxonomic data.

Despite the existence of the Linnean system for naming species, different names are used for the same species, and the same names for different species, because of the difficulties in communicating accurate knowledge to users. This leads to considerable confusion, and may cause regulatory problems where a species is listed as a priority for protection under an incorrect name. There will always be debate amongst taxonomic specialists about which name is more correct for some species, but a standard working list of names is essential for non-specialists to use. ERMS produced the first such list for marine species in Europe. This project is described here as an example of a first step in developing electronic species information systems.

The European Register of Marine Species

ERMS was a project funded by the European Union Marine Science and Technology (MAST) research programme (Concerted Action project number MAS3-CT97-0146). Its full title was "A register of marine species in Europe to facilitate marine biodiversity research and management," and its web address is www.erms.biol.soton.ac.uk. From 1998 until 2000, the project:

- Produced a checklist of over 29,000 marine fauna and flora species in Europe;
- Developed a database of some 800 scientists from 37 countries with expertise in the identification of marine species and/or their taxonomy;
- Compiled a bibliography of 600 guides for the identification of marine species; and
- Surveyed the state of marine species collections in Europe.

This information was subject to 'gap-analysis' to objectively identify where identification guides are most needed, in what taxa most species remain to be discovered, and where expertise is weakest.

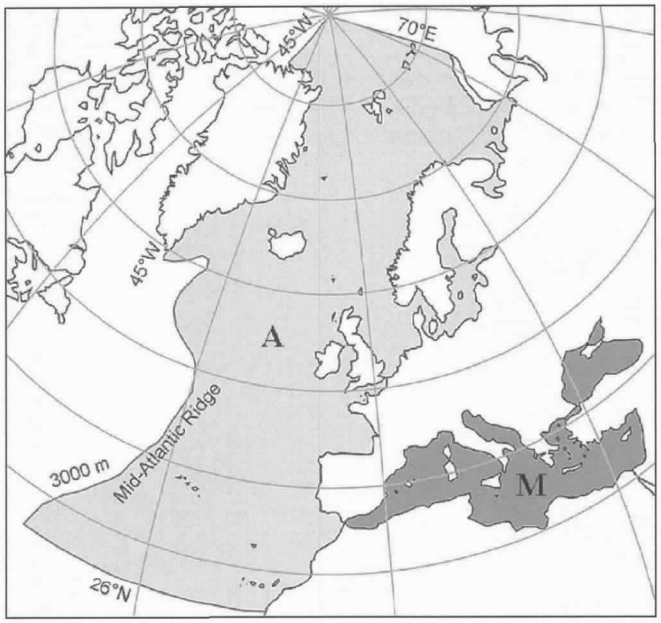

Figure 1. The geographic scope of the ERMS project. A = Atlantic Ocean including Arctic and Baltic Sea, M = Mediterranean Sea and Black Sea.

It is anticipated that the Register will become a standard reference and technological tool for marine biodiversity training, research and management in Europe. The species register can be used to:

- Check the spelling or find the correct name of a species and the authority;
- For a given species, check what other (or how many) species exist in the same genus, family or higher taxa. These species may not be included in the local identification guides;
- Find information on the distribution of species among higher taxa;
- Indicate the level of knowledge of a group of species by analyzing the rate of discovery of species.

Geographic coverage

The ERMS project included species occurring in the marine environment. This was broadly defined to include intertidal (littoral) and brackish water habitats, defined as up to the strandline or splash zone above the high tide mark and down to 0.5 ppt salinity in estuaries. The northern parts of the Baltic Sea are more freshwater than brackish, and it was left to the discretion of list compilers whether to include species there within ERMS or not.

The EU contract was limited to the European continental shelf. However, in Mediterranean and Norwegian waters the deep-sea is almost coastal and so-called deep-sea species can occur in shallower waters at colder temperatures. Consequently, the project did not distinguish between shelf and so-called deep sea species, and both were included. The study area was thus defined broadly as 'European seas' following the database of European Mollusca (CLEMAM) (Figure 1). These range from the North Pole along the east-coast of Greenland to Iceland, along the mid-Atlantic ridge, across the 26°N parallel to the coast of Africa, and into the Mediterranean and Black Sea. This inclusion of the islands of Madeira, Azores and Canaries brought sub-tropical species into the ERMS; such species coverage had generally been excluded from previous reviews of European marine fauna and flora. The species register was weak with respect to expertise for the 'deep' sea, Black Sea, Arctic Ocean and southern limits of the study area, because the mechanism of funding was limited to cover the European Union and European Economic Area (EEA) countries. Future work should involve the expertise of scientists where-ever they are based so as to fill these gaps.

Species included

The check-list included over 29,000 species representing all marine taxa in Europe. Only published and taxonomically available species names were included. With very few exceptions, only species whose occurrence in the ERMS area (Figure 1) had been previously published were included. Synonyms and other names for a species have been included in some instances. Parts of a few small groups were not fully covered, namely non-Halacaridae Acarina, and the Rotifera (Rotatoria) and Brachiopoda lists were limited to north-east Atlantic species.

Although not part of the EC contract, species lists of several protist groups and fungi were compiled through coordination by Sue Brandt and Nick Clipson respectively. Lichens, phytoplankton and cyanobacteria were excluded from the contract and project. Saltmarsh angiosperm plants were also excluded, as these are generally included in terrestrial plant classifications. It was not possible to use the species concept in a similar manner for bacteria (Eubacteria and Archaea) and viruses, so these groups were also excluded from the project. Future work should compile lists for all taxa where the species concept is applicable.

Methodology

ERMS had a budget of 385,000 Euro, 22 partner institutes (Table 1), and over 150 collaborating scientists (Table 2) in 18 countries. It relied on considerable voluntary effort by many scientists, for example in preparing species lists and/or in 'peer-reviewing' them. The funding was essential for travel costs to meetings, and to cover the time of scientists (only a few could use their host institute salaries for this work and some were privately employed). The funding and EC contract were invaluable in setting targets, deadlines, deliverables, and a timetable to manage the project and so achieve results rapidly.

Through collaboration, the project brought together existing knowledge into distinct end-products (Figure 2). It did not involve new field, laboratory or information

TABLE 1
Organizations participating in the European Register of Marine Species project. In addition to the countries below, individual participants (Table 2) were also based in Belgium, Croatia, Denmark, Japan, Portugal, Russia, Sweden, and USA.

Organization	*City*	*Country*
Université de la Mediterranée -Aix-Marseille II, Centre d'Océanologie	Marseille	France
Muséum National d'Histoire Naturelle	Paris	France
Intergovernmental Oceanographic Commission	Paris	France
DIVERSITAS -UNESCO	Paris	France
Forschungsinstitut Senckenberg	Frankfurt	Germany
Institut für Meereskunde, Universität	Hamburg	Germany
National and Capodistrian University of Athens	Athens	Greece
Institute of Marine Biology of Crete	Heraklion	Greece
Ecological Consultancy Services Limited (EcoServe)	Dublin	Ireland
National University of Ireland	Galway	Ireland
Universita degli studi di Padova	Padova	Italy
University of Amsterdam	Amsterdam	Netherlands
Nationaal Natuurhistorisch Museum	Leiden	Netherlands
Nederlands Instituut voor Oecologisch Onderzoek	Yerseke	Netherlands
University of Bergen	Bergen	Norway
Norwegian University of Science & Technology, Biologiske Stasjon	Trondheim	Norway
Museo Nacional de Ciencas Naturales	Madrid	Spain
Department of Zoology, Natural History Museum	London	UK
Marine Information Team, Joint Nature Conservation Committee	Peterborough	UK
Plymouth Marine Laboratory	Plymouth	UK
The University of Reading	Reading	UK
University of Southampton	Southampton	UK

technology research. In the first year of the project, it developed a web site, data management plan, intellectual property rights agreement, communicated with end-user organizations and biodiversity related projects, drafted a register of 1,300 experts in European marine species identification, and compiled a bibliography of guides to the identification of marine species.

Species lists were provided to the project electronically, as spreadsheets and text files. These were converted into web pages and print-out ('rich text format,' rtf) files for publication by Richard White. The 'holding format' that automatically converts lists into web page and print-out formats has links to the source files, and the list compilers contact details. It thus provides a simple relational database. Future projects will need to build this information into a more structured relational database.

Some lists had additional information on species distribution and other comments that

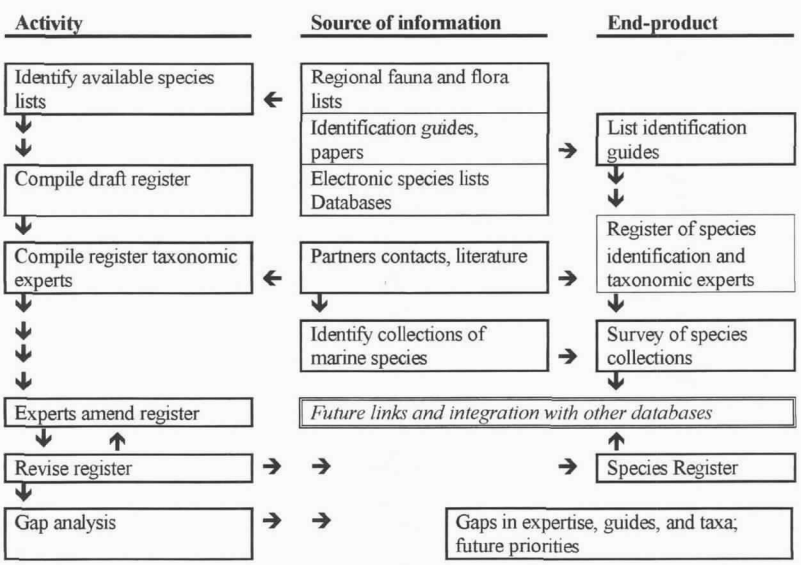

Figure 2. A diagram illustrating the elements of the European Reguster of Marine Species project, including activities, information sources, and end-products.

TABLE 2

The people who contributed to ERMS, either through compiling or commenting on species lists, and/or assisting other aspects of the project management through providing advice or taking more active roles. This includes a few persons who indirectly assisted ERMS through contributing to lists and databases from which species lists were taken.

Lists complied by

Agatha, S.
Bailly, N.
Bartsch, I.
Bellan, G.
Bellan-Santini, D.
Bird, G.
Bouchet, P.
Boxshall, G.
Brandt, S.
Brattegard, T.
Bray, R.
Bruce, A.
Cairns, S. D.
Clipson, N.
Connor, D.
Cornelius, P.
Costello, M. J.
d'Hondt, J. L.
De Smet, G.
den Hartog, J. H.
Dick, M.
Emig, C.
Erséus, C.
Faubel, A.
Giannuzzi-Savelli, R.
Gibson, D.
Gibson, R.
Gofas, S.
Goodkov, A.
Grasshoff, M.
Gross, O.
Guerra, A.
Guiry, M. D.
Hallan, J.
Hansson, H. G.
Hayward, P. J.
Healy, B.
Heppell, D.
Hirano, Y. M.
Hoeksema, B. W.
Hoisaeter, T.
Horne, D.
Howson, C.
Huys, R.
Jankowski, A. W.
Jarms, G.
Kapp, H.
Karlsbakk, E.
Krapp, F.
Landy, E.
Le Renard, J.
Legakis, A.
Lozouet, P.
Mapstone, G. M.
Markham, J. C.
Meisterfeld, R.
Minelli, A.
Monniot, C.
Mora Porteiro, F.
Mulisch, M.
Murray, D.
Neuhaus, B.
Noreña, C.
O'Reilly, M.
Opresko, D. M.
Otte, M.
Platts, E.
Ramos, M.
Rogerson, A.
Schuchert, P.
Serrão Santos, R.
Smith, S.
Sneli, J.-A.
Southward, A.
Southward, E.
Steyaert, M.
Templado, J.
Tendal, O.
Türkay, M.
van der Land, J.
van Ofwegen, L.
van Soest, R. W. M.
Vanaverbeke, J.
Vanhove, S.
Vanreusel, A.
Vervoort, W.
Vincx, M.
Warén, A.
Watling, L.
Whittaker, J.
Williams, G. C.

Assisted by

Arvanitidis, K.
Bachelet, G.
Bamber, R.
Barnick, R.
Bartoli, P.
Boury-Esnault, N.
Bremer, G.
Child
Collier, L.
Dauvin, J. C.
Dimitrova, Z. M.
Elbrächter, M.
Euzet, L.
Fagerholm, H.-P.
Fiege, D.
Furnari, G.
Garrido, M.
Gebruk, A.
Gentil, F.
Gorgiev, B. B.
Gutu, M.
Harmelin, J.
Holthe, T.
Jones, G.
Kearn, G.
Kennedy, C. R.
Køoie, M.
Lawson, S.
Massin, C.
Mironov, A.
Moravec, F.
Nic Dhonncha, E.
Noel, P.
O'Reilly, M.
Petersen, M. E.
Pugh, P. R.
Riemann, F.
Riemann-Zürneck, K.
Rindi, F.
Ruffo, S.
Ryland, J.
Saiz-Salinas, J. I.
Smirnov, A.
Stock, J.
Stöhr, S.
Zavodnik, D.
Zibrowius, H.

Assisted project management

Aricò, S.
Bailly, N.
Bellan-Santini, D.
Bisby, F.
Bouchet, P.
Boxshall, G.
Brandt, S.
Brattegard, T.
Connor, D.
Costello, M. J.
Emblow, C.
Guiry, M. D.
Harding, P.
Heip, C.
Hummel, H.
Karakassis, I.
Lasserre, P.
Legakis, A.
Los, W.
Marmayou, J.
Merin, L.
Minelli, A.
Patching, J. W.
Radach, G.
Ramos, M. A.
Scheller, U.
Skule Adam, C.
Sneli, J.-A.
Tuerkay, M.
van der Land, J.
Weslawski, J. M.
White, R. J.

TABLE 3
Examples of the global, inter-governmental and governmental organizations and projects contacted by ERMS during its development. The project participants also contacted additional national organizations.

- Species 2000
- Diversitas
- Convention of Biological Diversity (CDB) SSBSTA
- CBD Clearing House Mechanism and
- CBD Jakarta Marine Mandate
- Food and Agriculture Organization (FAO)
- International Maritime Organization (IMO)
- International Union for Conservation of Nature (IUCN) European Regional Office
- IUCN Species Information system
- ICLARM
- European Commission Directorate General for Research
- European Environment Agency (EEA) marine and database experts
- MarLIN (Marine Life Information Network UK)
- CIESM (compiling a list of exotic marine species in Mediterranean)
- Mediterranean Action Plan (Barcelona Convention)
- Council of Europe Bern Convention
- HELCOM (Helsinki Commission)
- OSPARCOM (Oslo-Paris Commission)
- Nordic Council
- International Council for the Exploration of the Sea (ICES)
- ICES Benthos Working Group
- BIOSIS
- Nature Conservation Topic Centre Paris
- European Topic Centre Marine/Coastal (ETC -M/C) Rome

OTHER EUROPEAN PROJECTS

- BioMARE
- Fauna Europea
- BIOCISE (Biological Collections Information Systems)
- Ballast water introductions
- Arctic Monitoring and Assessment Programme (AMAP)
- Baltic Marine Biologists
- Black Sea
- MARS (Marine Research Stations of Europe)
- Medifauna
- BIOICE
- BioOcean
- OBIS (Ocean Biogeographic Information System)
- National Science Foundation USA
- National Oceanographic Data Centre of NOAA USA
- Smithsonian Insitute
- ITIS (Integrated Taxonomic Information system)
- Euro+Med Plantbase (Flora Europaea)

were not included in the project publications so as to maintain as much uniformity between lists as possible. It is anticipated that future editions of this volume will include such additional information.

External interactions

It is anticipated that the Register will become a standard reference (and technological tool) for marine biodiversity training, research and management in Europe. However, to fulfil this it will need to develop and link with other expert systems at local, regional, global, governmental, and taxonomic levels. To this end, a special working group led by Frank Bisby communicated with over 40 global, European and North American organizations, projects, and initiatives (Table 3). This aimed to

- Create awareness of ERMS,
- Foster collaboration,
- Encourage data exchange,
- Invite comments from potential end-users,
- Maximize synergy of effort,
- Minimize overlap with other work,
- Stimulate related activities, and
- Promote the use of the results.

Species 2000 aims to list all species in the world through a federation of lists on different taxa (www.sp2000.org). To date, all its lists have or are developing a global coverage. ERMS became the first regional member of Species 2000. Future work will need to develop electronic and expert systems for cross-referencing global lists of selected taxonomic groups with regional lists of many groups (such as ERMS).

With the assistance of the Linnean Society of London a network of species-information projects has now been established in Europe, collectively titled Species 2000 Europa. ERMS was the first of the three component projects to be conducted, and it covered both fauna and flora. The Fauna Europaea project will list all land and freshwater animals (excluding protists), probably at least 100,000 species, and record their occurrence in each country in Europe. The third component, Euro+Med Plantbase, covers the higher plants on land and in freshwater of Europe and neighboring Mediterranean countries. It will update the previously published Flora Europaea, a detailed synthesis of knowledge of Europe's flora, in electronic form. Despite these projects, there are gaps in the coverage of some taxa, for example protists, phytoplankton, charophytes and bryophytes.

Networking

While fewer people could produce the ERMS species lists, this would exclude many scientists from the network. This network was essential because the list alone is only the first step in using species names and there is a need to provide for its development in the long-term. The networking was also the first step in 'marketing' the ERMS results, with consequent reduction of overlapping initiatives, greater willingness of experts to participate, and greater importance attached

to the project. The cooperation in this project has demonstrated a vibrant cooperative and collegial spirit amongst the scientific community in Europe.

The networking begun in ERMS will be continued through a new EU marine biodiversity Concerted Action project called BIOMARE (established with support from the Marine Research Stations (MARS) network), that will start in 2000, and be extended through links with Fauna Europaea (www.faunaeur.org) and Species 2000 (www.sp2000.org).

A special society for the management of European biodiversity data

The project produced an intellectual property rights agreement between contributors and the project (Table 4). Such as agreement is essential at the start of a project involving many people and organizations from different countries to clarify what use will be made of the information provided, and who will use and own the data. ERMS learned from past projects that could not disseminate results electronically, or could not agree on new versions, because of the absence of a copyright agreement. It was important that the ERMS data sets would have a single contact point for publication and revision, and that new revisions could be authorized.

All contributors are members of a new organization that will own the project's results, called the *Society for the management of European biodiversity data Limited.* This is established as a not-for-profit company, with limited liability, and no shareholders, in Ireland. Thus contributors retain a collective ownership (as well as authorship of sections of publications) of the data. It is thus in their interest to ensure that it is properly managed and influence its long-term development. The Council of this society will stimulate, facilitate and guide the updating of the species register to improve it in terms of taxonomic accuracy, and its expansion into a relational database with more synonyms, geographic and other information.

The society will 'manage' by deciding how its data was used and not used, and who updated and developed it, rather than apply for its own funding, infrastructure and have a large staff. Nevertheless, it would have costs in maintenance of its electronic archives, web site and expenses for council members to meet. All 'contributors' to the society datasets would have the right to become members for life, and they would not have to pay a membership fee.

The aim of the Society is to make biodiversity data available for the benefit of science and environmental management; including the archiving of electronic biodiversity data and to encourage and facilitate data being given an 'added value' by being combined and linked with other data. A unique aspect of the society would be its role of archiving electronic biodiversity data that could be reused and built upon. This is something conventional libraries generally cannot cater for because it required an expert understanding of the data content and ability to decide on what were appropriate uses for the data.

While the initial impetus for forming the Society was for the long-term management of the European Register of Marine Species, the society may also fill a need for the long-term management of other European biodiversity datasets arising from multi-organization projects or whose owners felt the society was an appropriate home. Its scope is wider than 'marine' and thus provides an opportunity for the long-term management of terrestrial and freshwater electronic data sets.

The society could have a unique and important 'service' in filling a 'niche' not catered for by present organizations. It was noted that problems in the long-term management of data sets arose when people retired or moved jobs, and where collaborative projects involving several institutes and countries ended. In some cases, one institute may agree to manage the dataset for a period, but this was again due to the interest of staff there. Eventually, staff changes would result in the data not being maintained or not being made available (i.e. no staff who sufficiently understand the data to disseminate it). The society could provide an 'exit strategy' whereby such 'orphaned data' could be managed, built upon, and made available to researchers and end-users. By owning the dataset, the society would have the responsibility of ensuring it was maintained and made available for scientific research and other end-users as appropriate. Thus, the society could ask that the data be moved should staff changes that may affect the data management occur or be anticipated. The network of members in the society would help find suitable experts to take over the management of orphaned electronic data sets.

Gap analysis

The data were collected by the project in a standardized format, so that they could be analyzed to identify gaps that may highlight priorities for future research. Species discovery rates indicated that most species would be discovered in the taxonomic groups with small sized and many species, such as polychaete and turbellarian worms, and harpacticoid copepods. Similar results have been found for the British and Irish marine fauna (Costello et al., 1996). However, mathematical models are being applied to the data to predict the total number of species occurring in European seas (Costello and Wilson, in preparation). These findings indicate that more taxonomists in these groups would produce the greatest rate of discovery of what species occur in Europe.

The questionnaire survey of collections holding marine species in Europe (by A. Legakis) found that a lack of resources to maintain and catalogue collections was a common problem to both very large museums and small holdings. Analysis of the geographic cover-

TABLE 4

The standard intellectual property rights agreement between ERMS and its contributing scientists, including people who compiled species lists and conducted other scientific work that contributed to the project.

European Register of Marine Species

STANDARD AGREEMENT WITH CONTRIBUTORS

AGREEMENT WITH: .....

This document establishes the basis on which data and/or intellectual property is provided to the project European Register of Marine Species (ERMS). By contributing to ERMS you will be benefiting the scientific community in general by assisting the production of good quality information of use to scientists, regulators, students and society.
ERMS is a project funded by the EU entitled "A register of marine species in Europe to facilitate marine biodiversity research and management" contract no. MAS3-CT97-0146, to which 19 organizations are contracted. The project is represented by the co-ordinator, Ecological Consultancy Services Ltd, 17 Rathfarnham Road, Terenure, Dublin 6W, Ireland, and managed by a Steering Committee. In this document the contributor is .....
On completion of this project the results will be transferred to a new organization which will own, disseminate, and update them. Signatories to these Agreements with Contributors would become members of this new organization and thus have a say in its management.

The contributor hereby
1. agrees to voluntarily provide data, information, opinion, or other expert assistance to the ERMS project,
2. retains the right to use and publish any data and intellectual property created by the contributor,
3. authorises the project to store, compile, modify, and disseminate data provided and derived by any means (e.g. electronic, World Wide Web, book),
4. recognises that products of the ERMS are the copyright of the project and will not further disseminate ERMS publications or data without prior permission of the project Steering Committee.

The project hereby agrees to
1. acknowledge the contribution of the contributor in publications of ERMS,
2. provide the contributor with a copy of ERMS publications,
3. establish a new organization to manage ERMS after this project is completed on 31st March 2000,
4. transfer all ownership of data and intellectual property collected as part of this project to the new organization by 31st March 2000,
5. ensure the contributor has the right to elect individuals to the management committee of this new organization.

The agreement shall remain in force until either party notifies the other in writing that it wishes to discontinue it. Such notification would not be retrospective. This agreement will come into force when the contributor has provided data or other documented expertise or assistance to the ERMS project.

Authorised signature on behalf of ERMS

Authorised signature on behalf of the Contributor

age of species identification guides (by P. Bouchet and J. Marmayou) found fewer guides for southern European seas (both Atlantic and Mediterranean) where most species occur, than in northern Europe. There were only adequate guides for fish in terms of geographic coverage and being up to date. Clearly, good species identification can only be conducted when comprehensive and current identification guides are available. However, there are no special national or European initiatives to fund the production of such guides.

Future development

The ERMS project was not only a first in its geographic extent and range of taxa covered, but also exceeded its contractual obligations with respect to taxonomic and geographic coverage. The present lists in

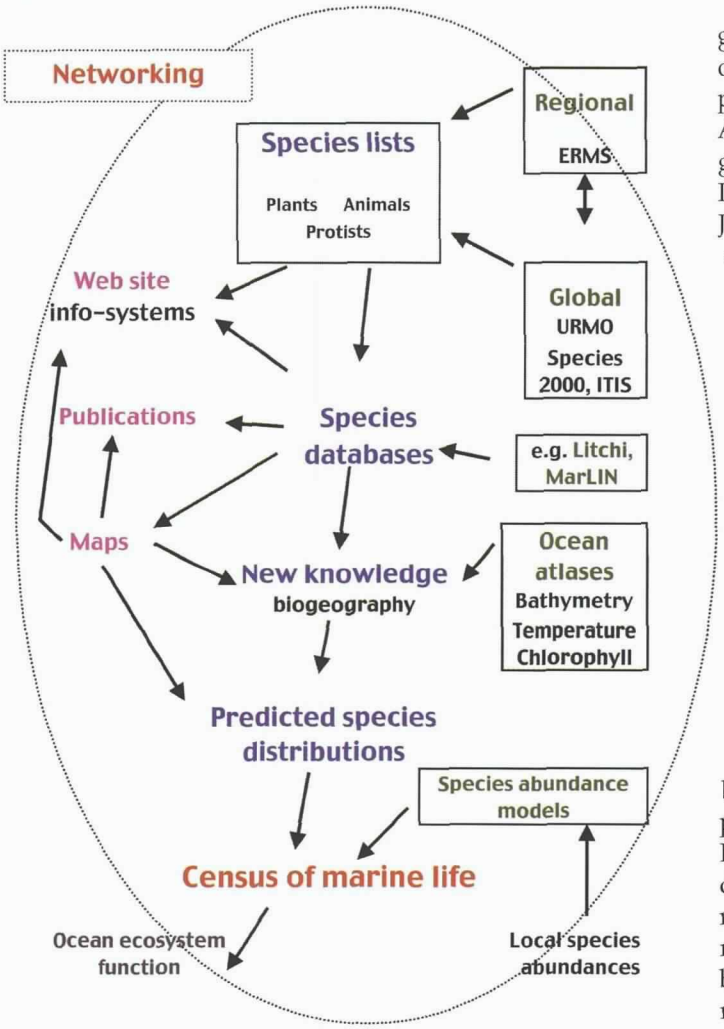

Figure 3. A possible framework for specied information system projects that could collectively produce a Census of Marine Life, with examples of some existing projects (ERMS, URMO, Litchi, MarLIN).

ERMS vary in quality because of the availability of recent reviews of taxa, existing databases, and time available for people to produce and check them. They will continue to be updated as new knowledge becomes available, under the authority of the Society for the management of European biodiversity data.

Lists such as ERMS should be expanded geographically or cross-referenced to lists in other parts of the world. A stepwise progression would involve the production of Arctic Ocean, North Atlantic, and all Atlantic species registers. Ultimately, there will be a global list of all marine species, such as the UNESCO-IOC Register of Marine Species being developed by Jacob van der Land (www.eti2.eti.uva.nl/-database/urmo), with which regional and national lists can be cross-referenced.

Already, some marine species lists are within databases that hold considerable additional data on the species distribution, ecology and/or biology. Examples include

- FishBase (www.fishbase.org),
- seaweeds (www.seaweed.ie),
- European molluscs (www.mnhn.fr/base/malaco.html),
- bryozoans (www.civgeo.mit.edu.au/-bryozoa/indexes.html),
- sea anemones (biocomplexity.nhm.ukans.edu/-anemones/images/index.html), and
- European ostracods (not available on the web).

Knowledge of species habitats and biogeography can be related to maps of the seabed and ocean waters, to provide maps of species distributions (Figure 3). Extrapolation of distribution information to abundances and biomass may be possible by counts of the numbers of individuals of a few large species of mammals and fish. However, for most species, models will be required to predict abundance (Figure 3). This will require taxonomic and ecological research, the production of atlases of the marine environments of the world, and the development of new rapid survey methods. Thus a range of complementary research activities would be required to produce a Census of Marine Life.

REFERENCE

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