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Original article

A perspective on the Census of marine life. The role of natural history institutions for this programme

Rôle des instituts d'histoire naturelle pour le programme de Recensement de la vie marine

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Abstract

The Census of marine life programme (CoML) is expected to generate a large amount of information on the diversity, distribution, and abundance of marine communities, many of them new or poorly known. Institutions such as natural history museums can play a crucial role in providing the necessary tools to allow the CoML to advance knowledge in the fields of marine systematics and biogeography. These institutions can contribute taxonomic expertise to provide quality-controlled identifications of species; specimen collections to allow for cross-checking of occurrences and a historical context for new data; information, both paper and electronic, on taxonomy, ecology and other topics to enable researchers to review past work; education opportunities to inform the public about the results of current and past research on the marine world. Challenges for these institutions in the future include the recruitment, training, and retention of taxonomic experts, development of advanced molecular techniques for more reliable and faster species identification in certain groups, and integration of expertise and other taxonomic resources into research on scientific processes from start to finish.

Résumé

Le programme de Recensement de la vie marine devrait apporter une grande quantité d'informations sur la diversité, la distribution et l'abondance des communautés marines, dont beaucoup sont insuffisamment connues voire nouvelles. Des institutions comme les muséums d'histoire naturelle doivent jouer un rôle-clef en fournissant les outils nécessaires pour permettre à ce recensement de progresser dans les domaines de la systématique et de la biogéographie. Ces institutions peuvent contribuer à l'expertise taxinomique en contrôlant la qualité de l'identification des espèces. Leurs collections doivent permettre. Elles doivent fournir une information, sous forme papier et électronique, sur la taxinomie, l'écologie et d'autres thèmes pour permettre aux chercheurs d'accéder aux travaux passés. Elles peuvent enfin informer le public sur les résultats en cours et passés sur le monde marin. Le défi pour ces institutions est d'attirer, de former et de recruter des systématiciens, de développer les techniques moléculaires modernes pour une identification meilleure et plus rapide des espèces et d'intégrer les ressources taxinomiques et de détermination dans les processus de recherche et ce, du début à la fin des programmes.

Keywords: Taxonomy; Biogeography; Marine communities

Mots clés: Taxonomie; Biogéographie; Communautés marines

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1. Introduction

The overall objective of the Census of marine life (CoML) is to assess and explain the diversity, distribution, and abundance of marine organisms in the world oceans.

Taxonomy and taxonomists play an essential role in the studies of the diversity of life in the sea, its interaction with the physical environment and the effects of natural and human impacts. Taxonomists might not always in themselves generate new ideas but allow many new areas to open up.

For scientists doing ecological survey work of any kind in the marine environment, the lack of systematic expertise is crippling. In most cases, only certain groups can be studied in detail, others are listed by a major taxonomic category (order, class or phylum) and some are rarely accounted for at all (e.g. hydrozoans, bryozoans, all meiofaunal-sized phyla). Which fraction is identified depends on the geographic location. Certain areas have been well studied, others are poorly known. In addition, published identifications are often of dubious quality; unless voucher material has been deposited, specimens cannot be readily verified. Verification is important, e.g. since the role of invasive species may have been under-estimated in the marine environment.

For a CoML programme, taxonomic expertise is essential for surveying, collecting, monitoring and assessment of the present state of marine biodiversity at the click of a mouse.

There is an urgent need to revitalize the study of marine systematics and biogeography.

2. Expertise

Natural history museums provide most of the continuing effort in the area of taxonomic description and study of systematic and biogeographic relationships among organisms. These institutions represent the centres of networks of scientific expertise. They employ a large number of the world's taxonomic experts specialized in certain groups providing reliable identifications and research results on systematics and phylogeny.

They also provide assessment methods for diversity, using both morphological and molecular methods.

Members of essentially all major groups of animals are present in the marine environment. This phyletic diversity in itself makes systematic work difficult in that techniques used to identify and describe the specimens vary from simple microscopy to complex and highly specialized histology. The literature and terminology is also so different for these groups, nowadays hardly anybody can be said to be proficient in more than one group of organisms. This means that we cannot expect high quality work from generalists; we have to develop specialists to work on each of the major taxa.

The quality of taxonomic work varies enormously. The presence of undescribed species created and still creates problems in estimating the diversity. Major groups of organisms such as polychaetes, nematodes or gelatinous zooplankton are so under-studied that accurate estimates of biodiversity are jeopardized and many of the calculations performed in standard ecology are thrown off.

Reporting the wrong species creates problems for future studies. Unless these errors are corrected in the catalogues, the use of information from these catalogues becomes compromised; any biogeographic and ecological statements based on these records will automatically become suspect.

A complete census of all marine taxa is not feasible. Such a programme should be especially focused on under-studied groups. In addition a major upgrade of identifications made in previously issued studies, is needed to make them useful for biodiversity and biogeographic studies.

Three major areas of work can be identified. First is the development of primary information and the analysis of the relationships among the taxa. Second, the development of easy-to-use keys and other aids with illustrations must be supported. The third major task will be to get all the collection records checked and information updated.

Collections can be used to identify gaps as well as the molecular work that is needed.

Molecular studies are more and more used to resolve taxonomic and phylogenetic issues, sometimes supplementing the morphological studies. These studies require specially fixed specimens and not formalin-fixed ones as is the routine procedure for many marine collections. Nevertheless, the benefits of such studies can be great. For example, marine pelagic organisms have been found to have very extensive geographic distributions, often in all three oceans. Molecular studies are necessary to determine the genetic variability within these huge areas, and can be expected to reveal a number of cryptic species.

In response to the decreasing lack of expertise, initiatives have been taken to counteract the taxonomy crisis e.g. PEET in the USA and the New taxonomy initiative in the UK.

3. Collections

Natural history institutions and some oceanographic institutions serve as repositories for marine specimens and records. The collections provide the raw material for ongoing research on the taxonomy and systematics of marine organisms.

Museums mostly have collections arranged by systematic groups and species names. Oceanographic institutions usually hold ecological collections arranged based on geographic location. These institutions serve as scientific facilities and provide resource for the work of researchers in a variety of disciplines. Also, they constitute the record for past conditions and provide baseline data for studies of

global change, giving information about faunal composition in the past. Collections are archives of the ocean's biodiversity and genetic diversity. They represent more than 250 years of accumulated biological information. For example, the question whether as to species are really endemic or have been invaders in the past can be answered by looking through the historic collections.

There is a voyage of discovery to be made through existing collections and historical datasets to detect changes on decadal or centennial scales in species distributions and/or faunal assemblages.

For example, the Zoological Museum Amsterdam holds the Siboga collection, from 1899 to 1900 from the Indonesian archipelago. The Indo-Malayan region is probably the most diverse region we know and the collection contains many types of specimens of new species. It is possible to study long-term changes in the faunal composition in this region because the Siboga collection is at the moment digitized, and actualized. These data give information on geographic distribution and relative abundances of species. No absolute estimates of abundance or of biomass can be given because the methods of quantitative sampling were not sophisticated enough more than a 100 years ago. Nevertheless, when compared to the present day situation, changes in distribution and relative abundance of the different species give information about faunal changes in this region in the past century.

Ecological collections are stored by geographic region and sample location. These have mainly been made by oceanic research or fisheries research institutions although many of these have no tradition of keeping collections. Collections are usually thrown away after a certain number of years when a certain research programme has been finished.

The most important and extensive plankton collections still available are:

- The Calcofi (California cooperative oceanic fisheries investigations) collections at Scripps Institution of Oceanography, USA with more than 50 years of extensive net plankton samples.
- The CPR (Continuous plankton recorder) collections made by the SAHPOS foundation in Plymouth, UK also over more than 50 years, collected in the North Atlantic using one particular sampling device, the plankton recorder, towed along both specific designated transect lines and from ships of opportunity. The CPR samples are taken on a less organized grid, with more area coverage than the Calcofi samples. These are not net samples, so soft plankton is damaged, but they are useful for crustaceans.
- The (former) IOS (Institute oceanographic sciences, UK now Southampton oceanographic centre) collections, now housed in The Natural History Museum London, UK. They have extensive collections on midwater plankton from the North Atlantic for over 40 years plus other collections from around the world including older collections from the Antarctic.

Other institutions hold much smaller collections, e.g. the Zoological Museum Amsterdam holds collections from the North Atlantic (1980s), the Indo-Malaysian area and the Indian Ocean (1990s), plus a small collection from the North Sea (1960s).

In these samples, there are still quite a lot of groups not properly worked up.

For example, the Calcofi and North Sea collections were made with fisheries in mind, so they were mainly used for research on fish, fish larvae and fish eggs. Parts of the collections have been used by scientists interested in other groups but most of the collections have not been really worked on.

So, new knowledge about changes in faunal composition, relative abundances and, species distributions of plankton can be generated through these collections. In addition, old records give information on occurrence of invading species or establish whether they were already present in the region for long periods of time.

There is a lot of discussion about global change, but apart from the very long-term quite crude records in paleontology, we do not have many samples on decadal scales.

4. Information

Collections are accessible for researchers both as samples and, increasingly, as electronic information.

Taxonomic institutions provide substantial and extensive library and documentation facilities, both on paper and in multimedia electronic forms. These provide the essential background information for academic researchers and other interested parties such as conservation managers and nature conservation groups.

Recent developments in computer technology make it possible for systematists to include much more information in their studies than in previous years. These developments will depend on accurate and carefully identified material in the collections becoming linked not only to the localities at which they have been found, but also to the published information in the literature on all topics studied.

For primary species data, progress has been made to structure the scientific work and data management. It is now urgent to build upon these developments by addressing the many other fragmented (ecological and other) biodiversity databases. Linking ecological and systematic information is important. Furthermore, the exchange and linking of molecular and ecological information is stimulated and the taxonomic information in ecological research is validated.

Such a very large undertaking is essential to open opportunities to apply the structured and interoperable information domains in analysis and modelling of the environment.

The newly established Global biodiversity information facility (GBIF), through their national nodes, will have to rely heavily on the expertise built by the Natural History institutions.

The databases presently available at the institutions vary widely, containing species lists, ecological and invasion information, distribution and abundance data, or museum specimens. For example, the collections from the National Museum of Natural History, Smithsonian Institution (NMNH), USA represent current knowledge on taxonomy and on the history of names and synonyms. NMNH can thus provide the reconciliation for these collections by allowing researchers to return to the original specimens. Computer records for invertebrates are in worse shape than those for the fishes, with taxonomic accuracy for the polychaetes, e.g. varying between 20% and 80% depending upon particular factors. Only data collected during the past 50 years have been digitized but NMNH is developing a massive relational database for its entire collections.

The British Museum has digitized 140,000 of their 15–20 million specimens, with fish records far ahead of other groups. They have found that as many as 50% of the species names may be wrong.

Multimedia museum catalogues with their associated databases will end up being an important tool for looking up all sorts of information about every named species for both the researcher and the general public. All scientists will be able to access it and use it for their own studies. This function represents an expansion of the role of museum collections.

Generating information on subtle patterns and important trends from geographically related data through collection databases and analytical GIS tools will be an important task. In addition, formation of collaborative research frameworks for developing information and sharing data based on material held in collections and databases with origin in or relevance to developing countries to address particular issues in sustainable development and conservation will be important because most collecting institutions are situated in Europe, North America and Australia, while most of the biodiversity is in tropical parts of the world. Through consortia such as the European consortium of taxonomic facilities (CETAF) or the American Association of systematics collections (ASC), linking of existing networks is done and information is provided to individuals around the world.

5. Education

Taxonomic institutions are an important educational resource and provide a clear focus for informing the public, thus creating and helping build up public awareness on important issues such as natural resource conservation and sustainable use of marine living resources. They provide exhibitions and provide popular literature on natural history. The scientists employed by these institutions provide expert information for the media as text, illustrations or video.

Most of the research, particularly ecological and applied environmental research, is hindered by the taxonomic impediment—the diminishing availability worldwide of expertise to identify the fauna and flora of the world. The taxonomic impediment is of particular significance in ecosystems (potentially) suffering from anthropogenic activities even before their biodiversity has been assessed and the functioning of that ecosystem understood. Examples of such ecosystems include the soil communities of tropical rain forests under threat from logging or the deep-sea bottom communities in the vicinity of manganese nodule mining. Training of scientists involved in collection-based research and curation is vital and an integrated approach is the only way forward. Joint Master's and PhD programmes as well as general and specialist training of staff in the best practices of curation should be carried out. Collaboration between universities and museums provides the best opportunity for training. Funds for training have to come from government and private sources. Job opportunities for taxonomists using current technology and/or molecular techniques must be created.

6. Challenges for the future

Natural history institutions are indispensable to develop tools such as models able to conduct retrospective analysis and predictive extrapolation. Also, the development of tools for taxonomic identification/training is very urgent. We have to digitize taxonomic knowledge and make it easily accessible before the existing taxonomists and their expertise disappear.

The use of molecular research to define the genetic variation in plankton species is needed. These species have such huge distributional areas that variation is to be expected within the species. Also, the relationships between oceanic species and determination of the number of cryptic species in the ocean have to be clarified. I presume that there will be many more species than we can now identify with morphological methods. More taxonomic work and expertise is needed here.

Mid-water gelatinous plankton is another area of research that requires new sampling techniques other than nets that damage or never sample certain groups. This is an important region of the oceanic system and more expertise both in taxonomy and preservation of samples is needed here.

Exploration of the deep-sea and especially the benthopelagic layer (just above the bottom) where not much sampling has been done will also reveal new species. In addition to the time-consuming and costly operations of deep-sea sampling in general, the extra difficulties in getting sampling gear very close to the bottom have prevented much research on this layer in the past. New species can also be expected to be discovered here.

Natural history institutions can face the challenges by cooperation in both collection management and pooling taxonomic expertise. Digitizing of information in collections and developing tools for taxonomic identification to enhance dissemination of taxonomic knowledge are essential. In addition to the presence/absence data on species, abundance data are important and more GIS tools to link the data with environmental parameters should be developed for biodiversity studies.

Marine stations, fisheries and oceanography institutions can provide new material to fill in the gaps in collections and knowledge. Also, these institutions can collect material suitable for molecular taxonomy studies. Taxonomists can train technical personnel in identification and taxonomy for monitoring purposes or provide the basic information for computer-based identification programmes.

Research programmes should contain a taxonomic component as well as on data management and the dissemination of results in an accessible way.

To bring the CoML programme forward, there should be close cooperation between taxonomic and ecological research e.g. between taxonomic institutions, marine stations, and oceanographic and fisheries research institutions.

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