

**BIOGEOINFORMATICS OF HEXACORALLIA (CORALS, SEA ANEMONES, AND THEIR ALLIES):
INTERFACING GEOSPATIAL, TAXONOMIC, AND ENVIRONMENTAL DATA
FOR A GROUP OF MARINE INVERTEBRATES**

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III. Proposal

A. ABSTRACT

As part of the Census of Marine Life, we will create a taxonomic database to the Hexacorallia (phylum Cnidaria) that adds to the inventory of sea anemones compiled by Fautin (biocomplexity.nhm.ukans.edu/anemones/images/Version.html) all species of orders Ceriantharia (tube anemones; by Molodtsova), Scleractinia (“stony” or “true” corals; by Cairns and Veron), and Zoantharia (zoanths; by Ryland). Specimen-based, it will contain three-dimensional distribution data (including geospatial precision of each record) and bibliographic reference to description of each species. In addition to current features, an application by Ardelean will permit retrieval of data by all synonyms of a species, flagging taxonomic and nomenclatural problems. Interacting with this database will be physicochemical and ecological databases important to marine biogeography. The core databases will be those assembled and linked as part of the UNEP/GEF-funded program within the LOICZ (IGBP) Typology effort (www.nioz.nl/loicz). We will develop and adapt tools to allow interactive analyses of the biological and environmental data, including by visualization on map displays. This project will: link across spatial scales; greatly augment the minimal biogeographic data available for most benthic marine invertebrates; permit formulation and testing of biogeography and biodiversity models; and support forecasting and hindcasting of distribution changes due to environmental change.

B. Table of partnerships

Note 1: Dollar amounts requested are direct costs only, and are assigned to the cognizant PI in the absence of formal subcontract arrangements with an external partner. For a breakdown of projected actual (subcontracts plus KU) costs for each task, see the table on the budget justification page.

Note 2: Partners are tabulated in two sub-tables: those where an individual research participant is identified, and those with a primarily institutional or program-level participation.

Table B1: Partnerships involving identified individual experts

Partner -- Individual/ Institutional	Roles and Tasks	Request to NOPP, Yr 1	Resource-sharing, Yr 1	Request to NOPP, Yr 2	Resource-sharing, Yr 2
D. Fautin Univ. of Kansas Educational	PI; coordinator for taxonomy; taxonomist of sea anemones Leader: Tasks 1, 2a, 3	\$103,383	\$11,708 facilities	\$ 86,163	\$12,296 facilities
R. Buddemeier Kansas Geol. Survey Educational	Co-PI; coordinator for environmental databases, GIS Leader: Task 2b	\$ 41,110	\$ 4,806 facilities (KGS)	\$ 41,212	\$ 5,056 facilities (KGS)
S. Cairns Smithsonian Institution Government	Taxonomist of ahermatypic corals: assemble taxon list, literature, synonymies Leader: Task 4	\$ 2,500	Partner time (salary); facilities	\$ 2,500	Partner time (salary); facilities
T. Molodtsova Shirshov Inst. of Oceanology Government	Taxonomist of cerianthids: assemble and enter taxon list, literature, synonymies Leader: Task 7	\$ 11,920	Partner time (salary); facilities	\$ 9,190	Partner time (salary); facilities
J. Ryland Univ. of Wales Educational	Taxonomist of zoanths: assemble taxon list, literature, synonymies. Leader: Task 5	\$ 23,435	Partner time (salary); facilities	\$ 5,480	Partner time (salary); facilities
J. Veron Australian Inst. of Marine Sci. Government	Taxonomist of hermatypic corals: assemble taxon list, literature, synonymies Leader: Task 6	0	Partner time (salary); facilities	0	Partner time (salary); facilities
SUBTOTALS		\$182,348	\$16,514	\$144,545	\$17,352

Table B2: Institutional, Business, and Programmatic Partnerships

Partner Institutional	Roles and Tasks	Request to NOPP, Yr 1	Resource-sharing, Yr 1	Request to NOPP, Yr 2	Resource-sharing, Yr 2
LOICZ (IGBP) International	Development of global shallow-water databases plus synthesis and analysis tools; liaison with other IGBP (GLOBEC, JGOFS) and international programs (SCOR, IOC/UNESCO, UNEP)	0	Synergistic funding-\$20,000 (est); Coordination	0	Synergistic funding-\$20,000 (est); Coordination
ICLARM International	Integration with existing community-level databases; distribution of products	0	In-kind service; Data; Distribution	0	In-kind service; Data; Distribution
NCRI Nova Univ. Educational	Development of databases for website on coral and reef biodiversity/vulnerability	0	Synergistic funding, data, coordination	0	Synergistic funding, data, coordination
NOAA Biogeography Program Government	Coordination and sharing of data bases and applications being developed; dissemination and liaison	0	Data; In-kind service, coordination, application	0	Data; In-kind service, coordination, application
Bits & Parity Manila Business	Software and database development and maintenance	\$ 10,000	Inter-project design compatibility	\$ 10,000	Inter-project design compatibility
SUBTOTALS		\$ 10,000		\$ 10,000	
TOTALS		\$192,348	\$16,514	\$154,545	\$17,352

C. RELATIONSHIP TO NOPP OBJECTIVES

1. Research objectives and operational goals

Through the proposed research, we seek to **advance the goals of NOPP/GBIF** by linking taxonomic information to earth science databases and the tools of bioinformatics to permit interactive analyses of environmental and biogeographic issues. We will enhance access to distributional and taxonomic data for important benthic marine taxa by those needing such information, including managers and marine scientists. The results of the proposed research will also provide tools and conceptual approaches for linking the more narrowly defined approaches of bioinformatics and geoinformatics into the next generation of integrated bioenvironmental tools.

As part of the Census of Marine Life, we will produce a **species-centered, geo-referenced relational database** of corals, sea anemones, and their allies (phylum Cnidaria, class Anthozoa, subclass Hexacorallia). This biogeographic resource will include type locality(s) for each species, taken from the original description, and localities other than type locality for species for which they are available. Locality data will be geo-referenced in three dimensions and contain information on precision. Thus the database will also be a taxonomic resource since it will, *ipso facto*, contain a complete list of all species, with bibliographic reference to the description of each.

The results of this project will form a **component of the Ocean Biogeographical Information Systems (OBIS)**. Links will also be made through websites such as Tree of Life (Fautin and Romano 1997, 1999; Fautin et al. 1999), and it will be publicized through electronic lists for subjects such as marine biology, coral reefs, and Cnidaria, and for groups such as PEET grant recipients. Our complete inventory of taxa will be available to entities compiling electronic taxonomic lists such as Codes for Australian Aquatic Biota (CAAB; <http://www.marine.csiro.au/caab>), the Integrated Taxonomic Information System (ITIS; <http://www.itis.usda.gov/itis>), and Species2000 (<http://www.species2000.org>). These entities can incorporate our lists into their central inventories or they can link to our website, depending on the structure and philosophy of the enterprise.

The database will be specimen-based. Techniques being developed to collate and interpret biogeographic data from natural history museum collections rely on electronic catalogs of specimens. Such datasets are available

mainly for species of economic importance and the “charismatic megafauna.” For most of the Earth’s species – especially invertebrates and marine organisms – natural history museums contain too few reliably identified specimens to document much more than the fact of their existence, and few collections of these organisms are in electronic form. Thus there are no electronic museum data to “mine” for most taxa. Capturing specimen-level data from the published literature is more cost-efficient than doing so by examining museum specimens, and ensures a complete inventory for each taxon.

Thus, we will **add value and utility to knowledge** that is currently dispersed in the literature by assembling it in a manner accessible to and understandable by non-systematists. Ultimately, this centralized effort will become a distributed one: once they become available, electronic catalogs of museum holdings can be searched using the list of taxa we will compile to add locality records and improve resolution of geographic and environmental ranges.

This project also has a **direct educational component**. Although they lack direct economic importance, these animals are vital constituents of many high- and low-latitude, shallow- and deep-sea communities. At least six university students working on this project will learn about these important animals. Two graduate students (or one graduate student and one Honours student) will be fully supported for training in hexacoral systematics and geography, and two will be geographers specializing in GIS applications to bio- and environmental geography.

The capabilities of this system have been designed for sea anemones, members of hexacoral orders Actiniaria, Corallimorpharia, and Ptychodactiaria (Fautin 1999). Taxonomic, bibliographic, and museum data are currently in Microsoft Access, and ESRI® products such as ArcView and MapObjects are used to manipulate geospatial data. An Oracle functionality will be added to accommodate the proposed project. Type localities (1615 points) for all 1355 nominal species of sea anemones can be displayed on maps, alone or in combination with physical data such as bathymetry. Searches can be made using geographic criteria (e.g. species living at some depth or in some region), taxonomic criteria (e.g. museums holding type specimens of particular species, all species in a genus), bibliographic criteria (e.g. all species described by a particular person), etc.

Data of four sorts will be added. 1) Taxonomic and distributional information for three of the four other hexacoral orders (Ceriantharia [tube anemones], Scleractinia [“true” or “stony” corals], and Zoanthidea [anemone-like animals also termed Zoanthinaria]) will be added to the database. Total number of species in these three orders is somewhat greater than that of anemones. The proposed database will collect, collate, and make publicly available more than 140 person-years of experience in the systematics, biogeography, and biology of these animals. 2) A significant enhancement to the anemone database will be linkage of names so that a search by any species name will result in finding records for all species with which it has been considered synonymous or with which it has been confused. 3) Records from the grey literature, museums, or personal experience will be added as appropriate and time allows. Appearance in this database will constitute publication of data in the latter two categories. 4) Biological information such as symbionts and abundance, and technical information such as collection method will be accommodated.

We will assemble and/or provide access to, primarily by coordinated electronic links, **a library of environmental and habitat databases** known or expected to be relevant to the ecology and biogeography of hexacorals; they will contain data on physico-chemical parameters such as bathymetry, water temperature, chlorophyll content, nutrients, light, and salinity. We will adapt and develop **a basic package of simple tools** to allow interactive queries among taxonomic, environmental, and geospatial data. Statistical and geographic classification tools will allow analysis of organism distributions relative to those of potentially controlling factors. Interactive queries will allow predictions about areas where organisms may occur that have not been sampled, and permit forecasting and hindcasting of distributions with environmental change. Such functionalities will allow interactions with other datasets to create new types of knowledge. We will coordinate with other participants in the Census of Marine Life, and involve a broad cross-section of the potentially interested community to maximize constructive feedback for improved product effectiveness, to develop and demonstrate a wide range of applications, and to initiate follow-on developments.

2. Breadth of participation within the oceanographic community

Buddemeier (co-PI) is a member of the Scientific Steering and Executive Committees of the Land-Ocean Interactions in the Coastal Zone (LOICZ) (<http://www.nioz.nl/loicz>) program element of the International Geosphere-Biosphere Programme (IGBP) (<http://www.igbp.kva.se/>). LOICZ maintains active liaison with

GLOBEC (which is developing a fisheries-oriented ocean typology) and JGOFS, and is an active cooperator with IOC/UNESCO, particularly in the Global Ocean Observing System (GOOS). LOICZ also has a major contract with the Global Environmental Facility (GEF) of the UN Environment Programme (UNEP) to engage scientists from developing countries in a coordinated project to regionalize and then globalize coastal zone biogeochemical budgets, using a typologic (environmental classification) approach. This project, to conclude in 2001, will be closely coordinated with and will provide both databases and tools to integrate into the final products of the proposed Census of Marine Life project: Buddemeier is responsible for global coastal typology development and its application to the GEF project. Coordination will result in mutual economies, greatly expanded exposure and dissemination of the products and techniques through the oceanographic community, and a wide range of rapid applications of the products.

Involvement of the U.S. oceanographic community will be assured by close coordination with NOAA; Buddemeier serves on the Coastal Sector team (<http://www.nacc.usgcrp.gov/sectors/coasts/>) of the U. S. National Assessment process (<http://www.nacc.usgcrp.gov/>), and is a participant in the ongoing work of a Habitat Classification workshop sponsored by the National Marine Fisheries Service. Fautin (PI) is a member of the Taxonomic Directory Committee of the National Geographic Society's Sustainable Seas Expeditions

The National Coral Reef Institute at Nova Southeastern University (<http://www.nova.edu/ocean/ncri/>) has funded Buddemeier to develop a database to assess coral reef vulnerability and biodiversity, with the ultimate objective of prioritizing research and conservation efforts. The participation of NCRI, which enthusiastically supports the proposed research, provides compatible databases, tools, and applications that permit this Census of Marine Life proposal to build on existing initiatives rather than duplicating effort.

Access to the international marine resource community is enhanced by participation of the International Centre for Living Aquatic Resource Management (ICLARM). John McManus, director of its ReefBase Project (<http://www.cgiar.org/iclarm/resprg/reefbase/frameg/>), supports and is interested in cooperation with the proposed activities (see appended letter). He has previously offered to distribute Fautin's sea anemone database and Veron's reef-forming corals database along with ReefBase on a CD containing a compiled version of Access. The integrated database we propose will be an even more valuable adjunct to ReefBase, an ecosystem-level distributional database, for it will provide species-level biogeographic and taxonomic information about important reef formers and inhabitants. ReefBase is also a potential candidate organization to assume long-term operation and maintenance of the proposed database if that is required.

3. Long-term commitment to the proposed objectives

The taxonomic database of sea anemones is a component of Fautin's 5-year NSF grant "Inventory, systematics, and phylogeny of sea anemones: training of modern systematists and electronic dissemination of data" in the PEET program (Partnerships for Enhancing Expertise in Taxonomy – <http://www.nhm.ukans.edu/~peet/>). Georeferencing specimen data, which was not part of the original proposal, began with support of a supplement from the REU program (Research Experience for Undergraduates) in the special competition in bioinformatics. Its addition to the database was stimulated by the OBIS workshop in October 1997 (Grassle and Stocks 1999). Another REU supplement was awarded in the regular competition the following year, and others will be sought in future years. Fautin has been awarded a second 5-year PEET grant, "Sea anemone systematics: consolidation and synthesis of information," to begin on expiry of the first, in September 2000. It will fund entering all remaining anemone locality data. Thus much of Fautin's career has been devoted to such research. She is Curator in the KU Natural History Museum and Biodiversity Research Center, which is committed to systematic bioinformatics, and holds a courtesy appointment as Senior Scientist at the Kansas Geological Survey (both discussed below).

Throughout his career, Buddemeier has worked and published on issues of bioenvironmental interaction, with particular emphasis on environmental controls over the distribution and function of corals and coral reefs. He is in his second term on the Scientific Steering Committee of LOICZ, and has accepted significant responsibility in meeting long-term program objectives that match well with this proposal. A key commitment is his determination to make access to data and tools readily accessible on a long-term basis; hence the involvement of major agencies and potential distributing organizations such as ReefBase.

4. Resources shared among partners

A critical element of the proposed research is synergy among projects and organizations with overlapping goals and activities. Buddemeier's active involvement and leadership in the LOICZ program of environmental classification and data assembly, and the NCRI reef biodiversity/vulnerability project permit economical and compatible development of common data sets and tools to support the closely related but individually distinctive objectives of these organizations, of OBIS, of NOPP, and of ICLARM. The individual partners thus share resources invested in accumulation of their expertise and databases; the institutional partners share support for developing and disseminating bioenvironmental data according to a shared vision; and the overall effort results in both wide distribution of useful products, and in building capacity and infrastructure for further advances.

Cairns also has research support through the PEET program. The objectives of the program are to produce monographic treatments of taxa, to make the results of systematic research useful to people other than systematists and other than scientists, to convey those results through electronic means, and to forestall loss of expertise in systematics (e.g. Nierenberg 1999) by training a new generation of systematists. Some of the results and products of PEET research will contribute directly to the Census of Marine Life, and, reciprocally, the environmental and geospatial components can inform the systematics and provide trainees with a modern tool. Having information about these taxa together makes organizational sense: there are many bibliographic and collecting localities in common. It makes sense taxonomically as well: some sea anemones, for example, were described as zoanthids, all members of order Ptychodactylaria may belong to order Actiniaria (Cappola and Fautin in preparation), and all members of order Corallimorpharia probably belong to order Scleractinia (e.g. Fautin and Lowenstein 1994).

5. Cost-sharing

See the partnership table on pages 4-5.

D. RESEARCH AND TECHNICAL TASK DESCRIPTIONS

1. Description of research

SIGNIFICANCE and PHILOSOPHY: Identifying factors that explain the biogeography of a taxon can inform decisions about conservation and economic exploitation as well as address interests of ecologists and evolutionary biologists. Characterization of the world's seas by physico-chemical attributes such as depth, temperature, salinity, currents, and bottom type has become increasingly accurate and precise with modern technologies such as remote sensing and remotely-operated vehicles. Such technologies can also capture biological data such as chlorophyll content of water and other measures of productivity. Using geographic information technology, distribution of these features can be searched, visualized, and compared electronically to gain understanding of ocean dynamics.

Comparing distribution of the physico-chemical parameters with that of organisms is vital to understanding factors that govern organism distribution and abundance. Finding organisms in an unexpected place may imply conditions there have recently changed, measurements were made during an atypical time, or some unmeasured parameter is significant to the organisms. Taking advantage of the potential offered by the technology of geospatial analysis requires a sufficient quantity and quality of data through space and time. Difficulty in obtaining data is expressed on the website of the Mediterranean Marine Gap Analysis (<http://com.area.trieste.it/gap-analysis/>): "we experienced severe lack of uniform and recent biological data on the marine environment and difficulties in accessing and gathering the existing ones." Knowledge of the distribution and abundance of most marine organisms, by contrast with that of their environment, is only beginning to be automated (e.g. Garrabou 1998).

Existing electronic tools have been applied largely to organisms of commercial importance. There is economic incentive for the expensive development of analytical software, and, more cogently, the occurrence of the relatively few species involved is well documented and the organisms are generally accurately identified. Understanding the distribution of organisms not of direct economic importance can have economic value if the organisms are important to ecosystem functioning. They can also serve as proxies for economically important taxa (or their habitats) if distributions of organisms of the two groups are governed by some of the same factors. Perhaps most importantly, because species not of commercial value constitute the vast majority of the sea's biota, knowledge of them is

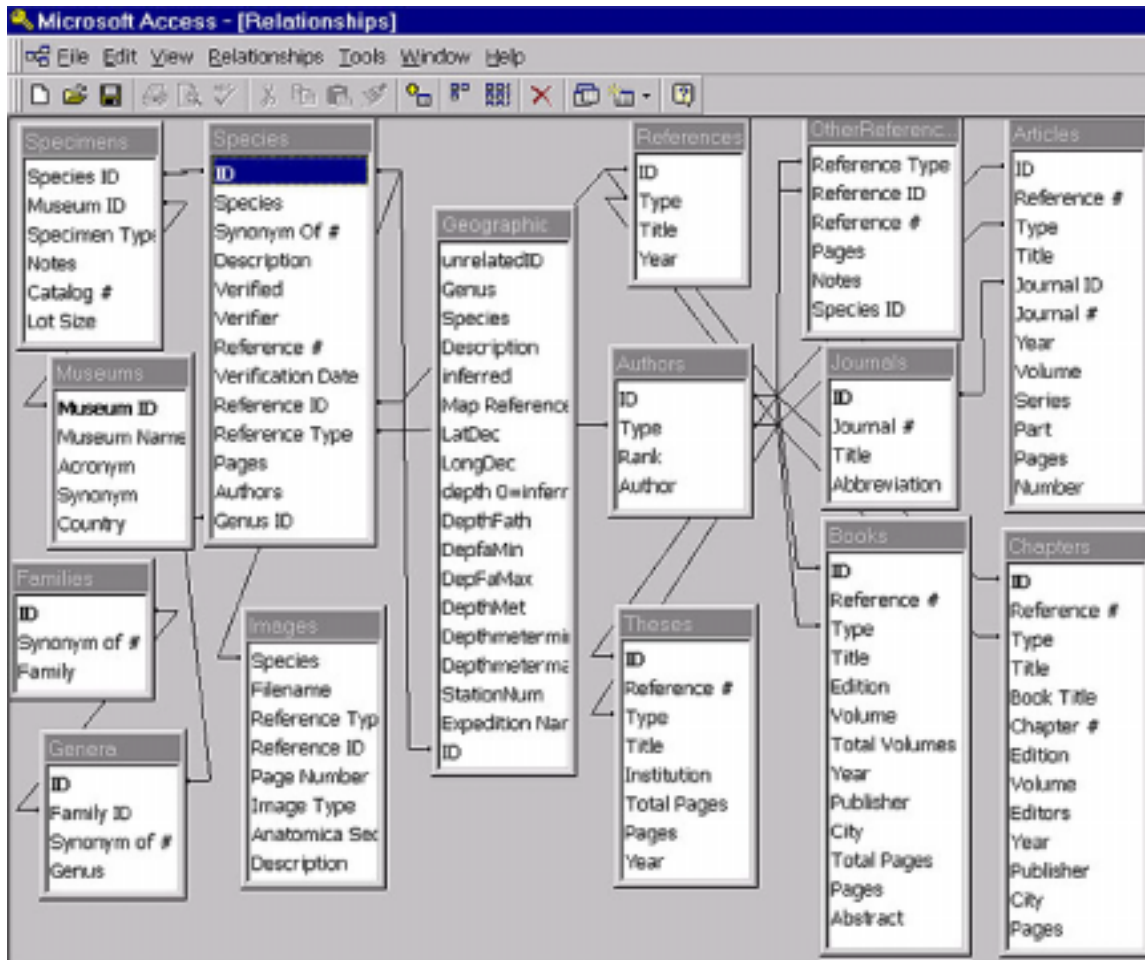
essential to understanding marine ecosystem function. A substantial obstacle to such knowledge is that experts must examine specimens to identify most species. Automated identification systems are still largely confined to the laboratory, and discriminate among few, abundant, commercially-valuable taxa (e.g. Pech-Pacheco and Alvarez-Borrego 1998); tools for remote identification are just beginning to be developed (Jaffe 1999, Parrish 1999).

TAXONOMIC COVERAGE and KNOWLEDGE BASE: To make information available about the biodiversity of corals, sea anemones, and their allies, we propose to develop an interactive, electronic atlas to them. In diversity, geographic extent, ecologic importance, and our relative ignorance of them, these members of phylum Cnidaria, class Anthozoa serve as an exemplar of marine invertebrates. They represent one subclass (Hexacorallia, also named Zoantharia) of 85 invertebrate classes (in 32 phyla of multicellular animals) (Pearse et al. 1987). Of the 75 classes aside from spiders, insects, and allied arthropods, 44 are exclusively marine, many others are mainly marine, and only two lack marine representatives. Thus an overwhelming proportion of major evolutionary lineages are represented by species that live mainly or only in the sea, arguably the most poorly-known habitat on earth. Biological knowledge – including geographic and habitat distribution – of most such animals is rudimentary.

Knowledge is best for those with commercial fisheries value, such as some members of classes Cephalopoda (Mollusca), Echinoidea (Echinodermata), Malacostraca (Arthropoda), and Demospongiae (Porifera). Sea anemones (order Actiniaria) are eaten in some countries (e.g. Dunn 1981), and substances of pharmaceutical interest have been isolated from some species (e.g. Dunn et al. 1975), including a toxin from a zoanthid of “complex and unique molecular structure” (Scheuer 1988, page 38). The primary direct economic value of hexacorals is among hard corals (order Scleractinia). In addition to the traditional value of their skeletons as building materials (e.g. Norse 1993, Berg et al. 1998), they are sold as curios, and a market in the aquarium trade has recently developed for live scleractinians as well as anemones (Carpenter and Niem 1998; Green and Shirley 1999). However, hexacorals are of extreme ecological importance in some habitats. The framework of coral reefs is built by scleractinians, and sea anemones dominate some habitats (e.g. Stephenson and Stephenson 1972; Dunn and Bakus 1977). Costanza et al. (1997) estimated worldwide annual quantifiable benefits of reefs to be US\$607,500 km⁻², and Berg et al. (1998) calculated those of Sri Lanka to be as much as US\$375,000 km⁻².

Internationally-recognized taxonomists will compile a complete inventory of nominal species for six of the seven hexacoral orders, along with the taxonomic authority for each. S. D. Cairns (ahermatypic Scleractinia), T. N. Molodtsova (Ceriantharia), J. S. Ryland (Zoanthidea), and J. E. N. Veron (hermatypic Scleractinia) will augment the database created by Fautin (1999) for sea anemones (Actiniaria, Corallimorpharia, and Ptychodactaria). This approach is in keeping with the OBIS philosophy of having a single authority responsible for each group (Grassle and Stocks 1999). Among products of this activity will be lists of species that can be arranged taxonomically, geographically, or by habitat, for example, and plots of taxa (species, genera, or families) on maps, alone or in combination with plots of physico-chemical parameters. Range maps can be abstracted from the point data. Such “maps convey important patterns, as well as subtleties and nuances of spatial variation in biodiversity...” (Gaston 1998, page 270). Having biogeographic information about all hexacoral taxa (except Antipatharia) together is likely to reveal patterns that could not be imagined if each taxon were considered alone. It will provide the opportunity to test ideas such as Fautin’s (1989) that distribution of the major orders of hexacorals is complementary at both global and local scales. It will permit determination of the level at which biogeographic units can be defined for Hexacorallia – the entire subclass, its orders, or some infraordinal unit.

Data to populate this database (data structure shown below) will be derived primarily from the literature. Museum collections have enormous potential to provide specimen-level data for biogeographic analyses (e.g. Soberon 1999), but limited access to information about collections in electronic format can prevent the potential being realized (e.g. Blackmore 1996). No catalog to a general collection of anemones, corals, or their allies is available on line, and none, to our knowledge, is even locally available, at a natural history museum; moreover, most specimens of these animals in the world’s natural history museums are unidentified. In lacking electronic data to “mine,” hexacorals are also typical of marine taxa.



Absent electronic catalogs to “mine,” data must be entered from print records. The literature shares an advantage with museum collections over contemporary surveys in inventorying biodiversity – both range through time as well as space. Although capturing data from either source requires time and other resources, it allows control over data format and quality. There are advantages to assembling data from publications rather than museums. The well-known problem of uneven quality of taxonomic information associated with museum specimens (e.g. Cohn 1995) is, in our opinion, less for published records because publication involves greater effort and fewer people. An inventory assembled strictly from museum specimens will inevitably be incomplete because some species are not represented in any museum collection, but every species must have been described in publication. At least for sea anemones, because there have been relatively few taxonomists, a high proportion of identified museum specimens (especially reliably identified ones) are those on which research has been published, so much the same data can be secured from the literature without the expense of travel to museums throughout the world.

GEOGRAPHIC COVERAGE and PRECISION: Coverage will be world-wide. The locality for each specimen will be specified in terms of latitude, longitude, and depth. Each locality record will be assigned a level of precision.

The current sea anemone database has six levels of precision for latitude/longitude, color-coded in the map display. "1" indicates latitude/longitude are provided in the original publication. Numbers 3 through 6 indicate diminishing precision -- geographic features such as cities or small islands merit a "3" whereas "Pacific Ocean" is a "6" (a few published records, coded "9999," do not provide any informative data). The number "2" indicates that latitude/longitude data come from other than the original species description. It may be from a separate publication (such as a station list) or from the specimen label (an anemone that was collected in the Sierra Mountains of northern California, according to published data, bore a label indicating it had been collected off Los Angeles: the published latitude was 38°N whereas the label gave the latitude as 33°N). Depth data have two levels of precision: "1" for a

depth that is provided in the publication and “0” for inferred depth. However, depth for many records must be left as unknown (“9999”). The user may select to have displayed only records of a particular precision.

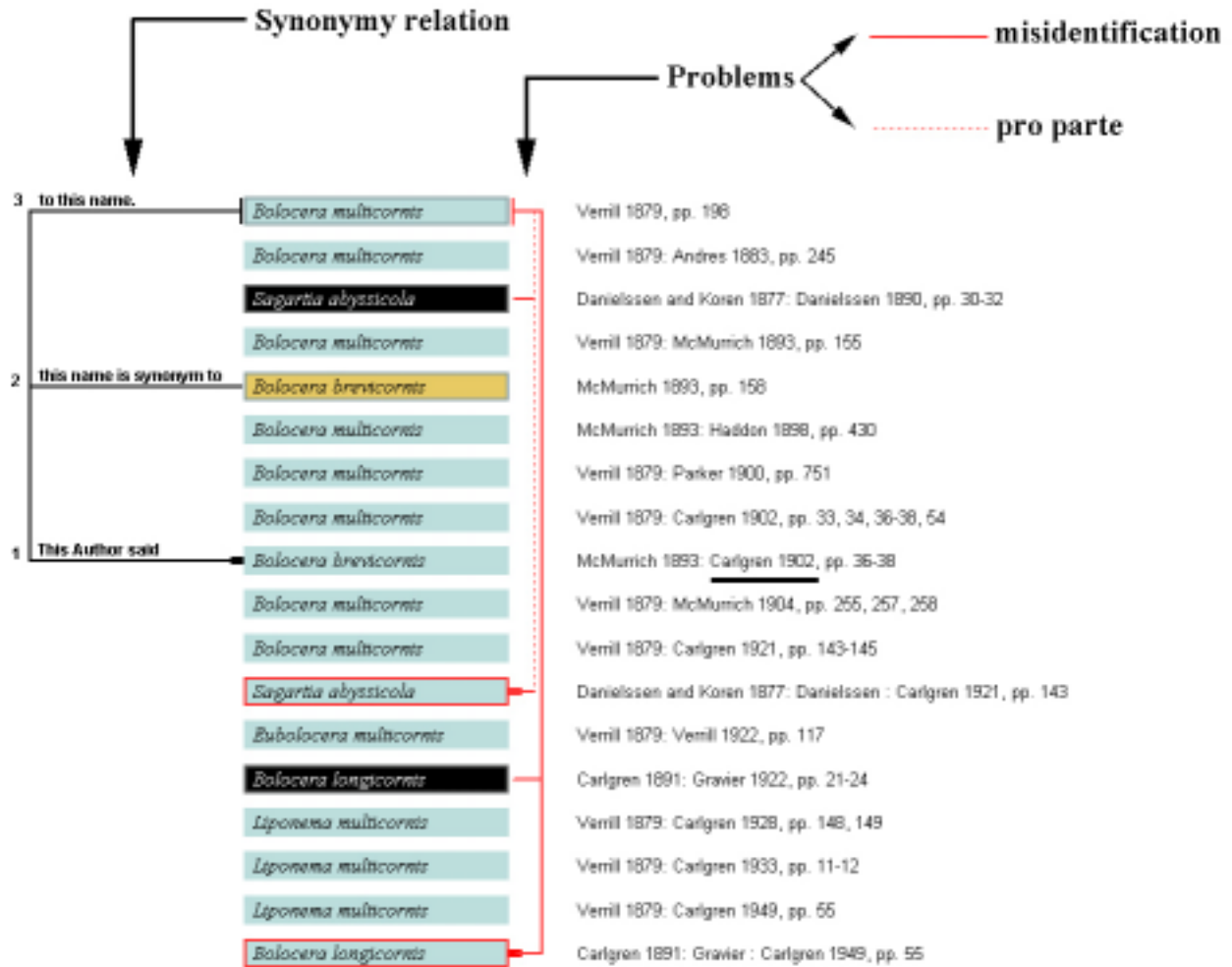
Data entry for a species begins with its description, which includes the type locality or localities – the place(s) from which the type specimen(s) was (were) collected. Range, being an emergent property of a taxon, requires locality records from many specimens. Number of records per species can be increased by adding specimen records. (For some hexacoral species, however, type locality is the current extent of geographical knowledge.) The major source of these data is the primary literature; such records are currently being captured for sea anemones. To the extent the collaborating taxonomists have assembled additional records or know of those in museums, such data can be included. They will be flagged as original, and the database will constitute their first publication. There may be valuable data that are neither original nor in the primary literature; data from the “grey literature,” such as species lists assembled for environmental surveys (e.g. Werner and Allen 1998) will be included at the discretion of the taxonomist. It will be the responsibility of the taxonomist to assign a level of reliability to both locality and taxonomic data for each such record.

Unquestioning use of a name can give a false sense of a species’ range. If the same species has been described under more than one name, it is likely to be more widespread than would be indicated by use of any of its names. Thus, a second way of increasing the number of locality records per species is to link synonymous names. The number of species names published (“nominal species”) is invariably greater than the number of species that exist (“valid species”). The ratio is about 2:1 for fishes (William Eschmeyer, personal communication), but for zoanthids it is 4:1 (Ryland personal communication) and for reef-forming corals about 4.5:1 (Veron personal communication).

SYNONYMIES: Complete lists of nominal species (such as in Fautin 1999) are rare. Commonly, lists include only valid species (e.g. Cairns et al. 1991, 1999). Data associated with names that are now considered junior synonyms cannot be used if the name is not recognized. Linking it to its senior synonym makes associated data available in a biologically relevant manner. For the purposes of this project, a complete list of species allows biogeographic and systematic analyses that are otherwise impossible. Reciprocally, to assess the real biodiversity of a taxon, it is essential to have taxonomic and nomenclatural information to determine which available names are valid.

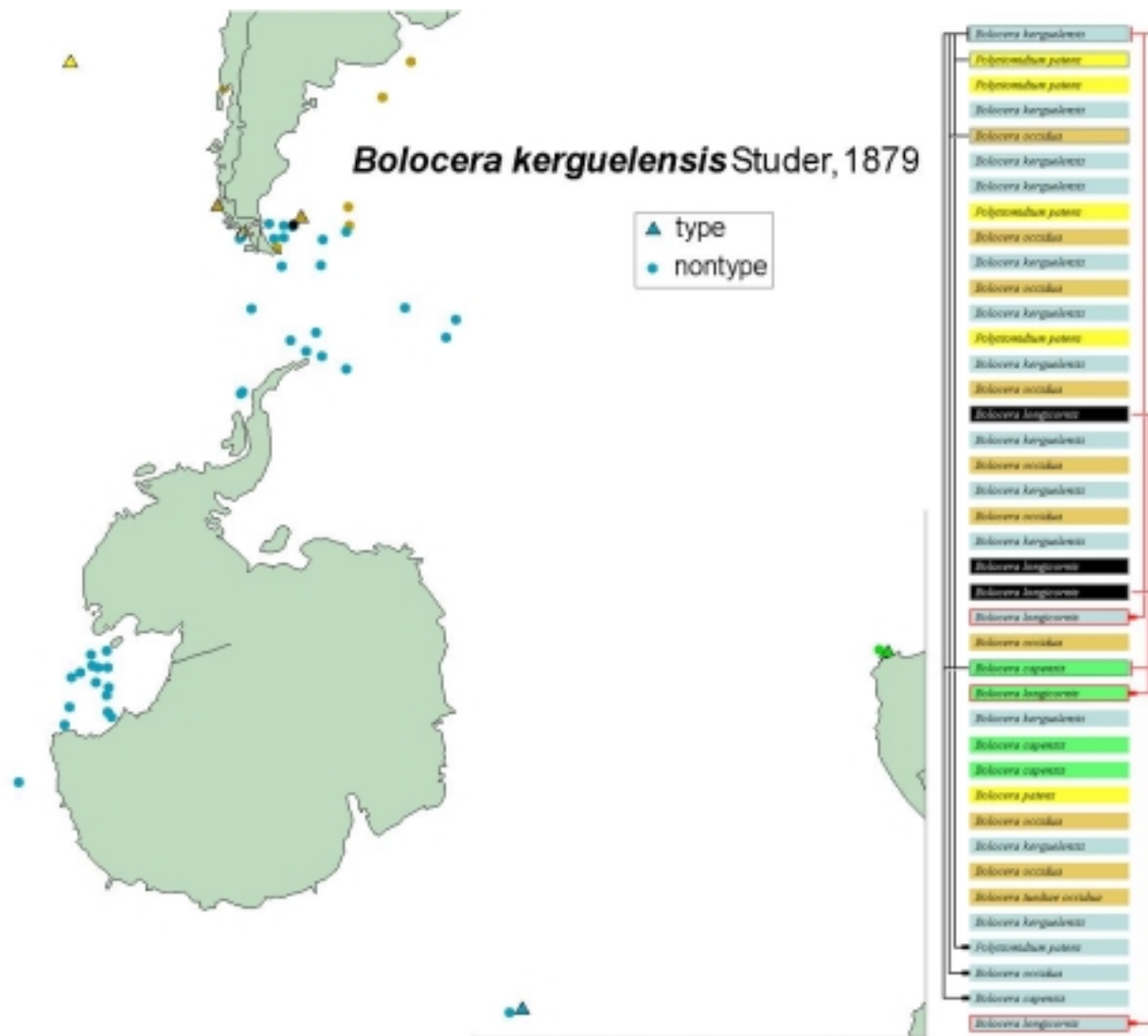
Fautin’s student Ardelean is developing a means to link names that are believed to be synonymous or that have been confused, and a convention to display these data. This is a complex exercise because opinions about synonymy may differ, a name may actually apply to only some of the specimens examined, specimens may have been misidentified, etc. In Ardelean’s application, names are displayed in an easily understandable graphic form, the nominal species are color-coded to distinguish them, and taxonomic and nomenclatural problems are indicated. (see figure on following page).

Liponema multicornis (Verrill, 1879)



The synonymies display will be expanded to accommodate unpublished opinions of the taxonomist assembling the information, with suitable symbology to indicate that fact. Display of such linkages on our website will constitute publication of that opinion. We anticipate two major categories of linkages between names. 1) Names that are synonymous in the opinion of the taxonomist but that have not been published as such. 2) Commonly confused names that are not synonyms. Thus, if *Aus bus* is often misidentified as *Cus dus*, linking them in the database will make anyone analyzing the biogeography of *Cus dus* aware that some records might actually refer to *Aus bus*.

Ardelean has developed a means to display locality data from the references in synonymous relationships, color-coded to the name used in the publication documenting the localities (see figure on following page). If, in a display, all the localities of one color are separated from the others, which are intermixed, it might be hypothesized that those are not, after all, synonymous names. Reciprocally, finding records of what is ostensibly a single species in separated clusters might indicate that representatives of more than one species were identified by that name. Simultaneous display of the distributions for more than one "valid" species will be possible, which will provide a means of identifying possible unrecognized synonyms.



ENHANCEMENTS TO THE SPECIES DATABASE: We will add capabilities and types of data to those currently in the anemone database. The database is not designed to allow a user to identify specimens (although information in it may be critical to identification), but it will be linked to websites designed for that purpose. Among such sites available now for anthozoans are electronic versions of what were written as hard-copy keys, such as Hand (1964). Identification aids written specifically to take advantage of computer capabilities are beginning to emerge – e.g. one to polychaete worms (Paterson et al. 1998). Through OBIS, the database can be linked to sites providing general information on hexacorals, such as Tree of Life (Fautin and Romano 1997, 1999; Fautin et al. 1999) and the UC/Berkeley Museum of Paleontology (<http://www.ucmp.berkeley.edu/cnidaria/cnidaria.html>). Information will be provided concerning an illustrated, interactive key on CD-ROM to the reef corals that was written by Veron to accompany his 3-volume treatment of corals of the world (Veron 2000).

Because the higher-level taxonomic organization of sea anemones has been fluid, family names are not included in the current database. The synonymies application will allow data at all taxonomic levels to be handled, thereby permitting searches at family level, as well as genus and species. Family assignments must be added for anemones and will become a routine part of the data entered for all taxa henceforth.

Fields will be added to accommodate biological information such as life stage or reproductive state (as in CephBase, the interactive database for cephalopods: <http://www.cephbase.dal.ca>). Of particular significance for hexacorals are

symbiotic relationships: these animals associate with organisms such as fishes (e.g. Fautin and Allen 1992), algae (e.g. Buddemeier and Fautin 1993), and crustaceans (e.g. Fautin et al. 1995). Because the first objective of this project is to develop a geospatial database, such data will not routinely be recorded, but can be if desired.

A field will be added for abundance to record such data if available. Abundance data are useful for many purposes, including commercial ones and conservation. Few taxonomic publications indicate abundance, other than the number of specimens examined. This can be misleading for the same reason that representation in natural history museum collections may be: specimens of some common species are few or lacking in many museums because they are of less interest to collectors and taxonomists than are uncommon ones. In ecological publications, which more consistently include abundance data, identifications may be incomplete or inaccurate. An estimate of the accuracy of the identification will accompany each such record.

Sampling methods are rarely recorded in the hexacoral taxonomic literature, unlike the oceanographic literature, but a field will be added for this attribute so the data can be recorded, if available. This may be particularly relevant to cerianthid larvae, to be added by Molodtsova.

As electronic catalogs of hexacoral specimens in natural history museums come on line, this database will become a distributed effort. A search by any name will be done by all names linked to it in the synonymies application. Provenance of specimens thereby located can supplement maps generated from the literature. As stated above, the specimens cited in publication, which populate the database, are likely to be archived in museums so a search may not turn up additional specimens, but it will allow at least a check of published data against those of the catalog, and procurement of any unpublished information. The exhaustive and accurate inventory of the database will provide museums with lists for catalogs, and complete bibliographic and locality data for each specimen in the collection that is included in the database, thereby saving museums time in capturing the data. A field will be added to accommodate catalog numbers, as is currently true for sea anemone type specimens. This field will be filled mainly when museums are searched: catalog numbers are rarely cited in publication. This feature will facilitate retrieval of particular specimens by users. All museums with significant hexacoral holdings will be kept apprised of progress on this database (as they are now for sea anemones) so they do not unnecessarily duplicate data acquisition.

PHYSICO-CHEMICAL and ECOLOGICAL DATABASES: As the first phase of integrating biogeographic with environmental data, we will concentrate on variables that are available as datasets of global or near-global coverage and meet either or both of the following criteria: 1) are significant definers of organism potential habitat, or forcing functions for environmental change and variability (including direct and indirect anthropogenic effects); 2) are potentially predictable into the future through ocean/atmosphere GCMs or other model projections (see, *inter alia*, <http://ipcc-ddc.cru.uea.ac.uk/> for examples of such variables). In addition, they must be consistent – that is, they must have a common proximate source, and share format, quality, QA/QC procedures, and scale/resolution.

The project will build on and extend the environmental dataset development being undertaken by LOICZ (as an example, see "Typology Dataset" at <http://www.nioz.nl/loicz>). The initial data assembly consisted of 36 primary variables (which totaled over 100 variables when subdivisions, such as seasonal or monthly data, were considered) aggregated into 1° cells over the world coastal zone, defined as +50 to -50 m of elevation. Data types included variables of climate (air temperature, precipitation, PAR, etc.), oceanography (bathymetry, wave energy, storms, currents, tide type and range, sea-surface temperature, salinity, etc.), land (soil type, elevation, vegetation, runoff, etc.), and the human dimension (population, GNP, cultivation, deforestation, etc.).

The on-going revision, update, and expansion of the LOICZ database will be complete by the time the work we propose begins. The revision includes: 1) an expanded definition of the coastal zone (depths <200m), with retention of global marine (pelagic) datasets for eventual interaction with other projects such as NOPP, GLOBEC, etc.; 2) a 0.5° grid, with provision for retention and application of higher-resolution data sets (e.g., 1-km DEM and 2-minute bathymetry); 3) use of updated datasets developed by other programs (e.g. global marine datasets are being provided by J. A. Kleypas, National Center for Atmospheric Research (NCAR), who is in a coordination role with the U. S. JGOFS project); and 4) linkage to the TYGRIS-BACH database of water, nutrient, and sediment fluxes from land to the coastal zone (C. Vorosmarty and M. Meybeck, IGBP-BAHC).

In the interests of developing a robust distributed system, links or references to existing data archives will be used as much as possible. An example of such an archive is SEDAC cataloged socioeconomic and earth science datasets (<http://www.gateway.ciesin.org/>). The distributed tools (see below) and database structure and contents will not be prescriptive or exclusive, but will provide users with a consistently developed and presented set of relevant variables while allowing for use of alternative, updated, or regional data sets for the same or different variables. In addition to being available in data file format, a core set of the most useful variables will be available as ArcView coverages, both for download and for interactive use on MapObjects server systems. Integration and application of the biogeographic database will be facilitated by linking the relevant layers through GIS.

RELATING TAXONOMIC AND ENVIRONMENTAL DATABASES: The definitive list of species will be arranged in the taxonomic hierarchy so searches can be made at any taxonomic level, as well as for any part of the world (in three dimensions), and bibliographically. All environmental data will be geospatially referenced so it will be possible to display concurrently, using ArcView overlay and query procedures, the selected organism locations with environmental variable distributions. The use of metadata standards appropriate to the data and community, and of standard, widely used relational database and GIS packages, augmented by straightforward macros and code, will ensure that the products can make use of other independently-developed analytical or display tools, and can be readily incorporated into or linked to other OBIS products.

The distribution of a taxon can be characterized not only by the three spatial dimensions and time, but also by parameters of the physico-chemical environment such as salinity and substratum. Thus the potential habitat of a taxon is n-dimensional. Multivariate analysis is required to develop the full power of the data associations needed to understand such a distribution. GIS modeling and analysis using multiple layers with ArcView and ArcInfo become tedious and are of limited utility with remote, web-based access. B. Maxwell has developed for LOICZ a prototype user-friendly clustering package designed for application to high-dimensionality data sets (<http://www.palantir.swarthmore.edu/~maxwell/loicz/>) that is now in the beta-test stage of Version 2. This software, which is compatible with ArcView, provides a means of clustering grid cells in terms of similarity (Euclidian distance) based on multiple variables. In the next version it will be possible to train the clustering process by testing for similarity to known habitat locations. This software will be used in the LOICZ Typology training for the regional synthesis workshops beginning in mid-2000, and we will incorporate it into our data integration products.

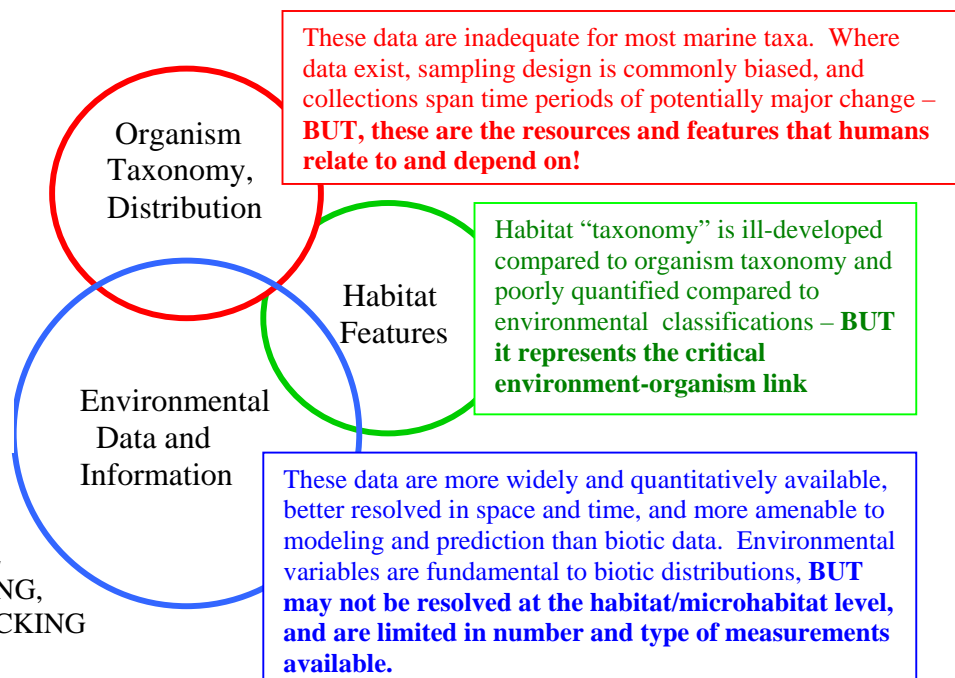
Work done to date on hermatypic coral distributions and reef potential habitat have shown the power of analyses using relatively few environmental variables to define, predict, and quantify suitable habitat. Kleypas (1997) and Kleypas et al. (1999) correlated coral reef distribution with environmental variables and developed distributional models and classification systems. Guinotte (<http://ghsun1.kgs.ukans.edu:8002/Lohtml/MxHhtml/website.html>) has extended this work to the regional level and demonstrated the power of higher resolution bathymetry to refine predictions of reef habitat.

Thus, adding the physico-chemical dimensions to a plot of the biogeography of a taxon may provide an explanation for the distribution of the animal. Further addition of the temporal dimension allows forecasting, which is of considerable concern in this era of global change. One test of the robustness of predictions is by hindcasting, which requires historical data. The records we propose to assemble provide a slice through time that is needed in any attempt at global assessment (e.g. Alldredge et al. 1999).

The following figure illustrates a key concept underlying the approach of this proposal. The three-way match of environmental, organismal and habitat characterization that is critical to definitive understanding of abundance, distribution, and biodiversity through time is rarely achieved. However, thoroughly documenting the ranges of overlap and probable relationship of any pair of variables can be a powerful tool for hypothesis development, and understanding of the other diads and ultimately the desired triple intersection. The proposed research not only addresses the organism-environment interactions, but will benefit from close association with the LOICZ efforts to characterize biogeochemical function on the basis of environmental variables – an approach that provides an integrating yet independent approach to ecosystem relationships.

Conceptual Overview
Relationships among organism distributions and environmental variables will be used to identify habitat characteristics that can help generalize poorly-known distributions over space and time – study of Hexacorallia, an important marine taxon, will provide conceptual models for other taxa and problems.

CONCURRENT USE OF ALL THREE COMPONENTS PROVIDE POWER, UNDERSTANDING, AND APPLICATIONS LACKING IN ANY ONE OR TWO



2. Task descriptions

Facilities other than those of KU are described; see section IIIF for KU facilities. Task-specific budget items are identified and are justified in the Budgetary Information section; participant qualifications are in the personnel section; scientific activities and references not in other sections of the proposal are specified here.

Task 1: PROJECT MANAGEMENT, INCLUDING DISSEMINATION OF RESULTS

Task Leader: Fautin. Other Personnel: Buddemeier, David, Bartley, Misgna, other support staff.

Subtask 1a: Coordination and integration -- design and specification of data and software formats and capabilities to ensure compatibility within the project, ease of access and application by the user community, and suitability for linkage to the overall OBIS system. An Oracle functionality will be created for the database to allow 1) multiple simultaneous users, 2) remote interaction with the database, 3) password protection for various levels of access, 4) batch entry of data, and 5) a QA/QC step for new data before they are incorporated into the database. Throughout the project, it will be responsible for monitoring schedules, deliverables, and QA/QC of products, and for ensuring that all components are effectively linked and combined. Facilities: See section IIIF. Estimated cost (travel, communications, software development, fraction of salaried personnel) \$5,647 (+ KGS match of \$9,862),

Subtask 1b: Product development and dissemination (information, education) -- this activity initially plans for conceptual and GIS components of the database and applications to ensure user -friendly access and compatibility with the WWW and individual distribution formats, and that they coordinate with other elements of OBIS. The task monitors progress throughout the project to identify problems and opportunities, and conducts a final integration test and preparation of demonstration and tutorial products to accompany distribution of the final products. Work conducted at widely separated locations will be coordinated through internet sites between personnel meetings. Fautin, Buddemeier, David, GIS and support staff in Kansas and the Philippines. Estimated cost \$73,281.

Task 2: DATABASES AND DATABASE APPLICATIONS

Subtask 2a: Nomenclatural and biogeographic databases and applications

Task Leader: Fautin. Other Personnel: Ardelean, David, students to be named, support staff. As part of this task, Ardelean will 1) refine the synonymies application, train users, and write documentation for it; 2) intermediate between Veron and David to ensure data on hermatypic scleractinians are translated appropriately; and 3) help Ryland and his student on data entry matters. Students will enter data from literature provided by Cairns. One will develop a gazetteer that contains georeferences for common localities for species in the database in order to speed data entry and minimize inconsistencies in latitude/longitude assigned to a feature described only in words; station lists for relevant expeditions and cruises (including those provided by Cairns for US government ships) will be

included. The gazetteer will be made available on the website with the database and its associated tools and linked sites as a biogeographic resource to the user community. Estimated cost \$68,982.

Subtask 2b: Environmental and habitat-related databases and applications

Task Leader: Buddemeier. Other Personnel: David, Bartley, Misgna, support staff.

This task will 1) identify and provide metadata and source information (electronic links where possible) for potentially useful data sets at scales of large regions (ocean basin or continent) to the globe, and 2) create direct access to a selected set of environmental data sets and GIS coverages that will be based on the LOICZ typology data (to be acquired from the most complete and up-to-date offerings of NOAA, NCAR, and other global data sources), appropriately extended to the open ocean as well as coastal zones. Estimated cost \$75,123.

Task 3: PTYCHODACTIARIA, ACTINIARIA, CORALLIMORPHARIA

Task Leader: Fautin. Other Personnel: Ardelean, students to be named. Estimated cost \$28,848.

State of taxonomic knowledge of the six orders to be included differs considerably. For the three with which Fautin built the database, bibliographies and all original names and type localities have been entered.

All synonymies, and all non-type taxonomic and locality data have been entered for the three species of Ptychodactiaria, all of which are considered valid. If Cappola, Fautin's PEET-supported post-doctoral fellow, determines that Ptychodactiaria should be integrated into Actiniaria, this order would disappear.

Of the 1306 nominal species of Actiniaria, perhaps 900-1000 are valid. As part of Ardelean's initial development of the synonymies application, non-type locality records were entered and synonymous names were linked for approximately 20 species. An REU student comparing the diversity of anemone faunas in the Arctic and Antarctic is currently entering synonymies for species relevant to his research. It is planned that next year a similar REU biogeographic research project will provide an opportunity to link other synonymous names. Under Fautin's current PEET grant, two Ph.D. students (including Ardelean) are revising taxa of Actiniaria. A post-doctoral fellow to be hired under her second PEET grant will revise a large genus of actinians. The students and post-doc will compile the locality and synonymy lists for the species that are the subject of their research. Entry of non-type localities for the remaining actinians (perhaps 800 species) will be supported on Fautin's second PEET grant.

Synonymies must be linked for all 50 nominal species of Corallimorpharia, of which an undetermined number is valid. This will be done as part of a Ph.D. project under Fautin's second PEET grant to revise, at the generic level, the entire order. The still-to-be-identified student, who will enter graduate school in August 2000, will spend part of his/her first academic year doing this to become acquainted with the group. Thus no project resources will be needed for this order, which Cappola is likely to conclude actually belongs among Scleractinia.

Task 4: AHERMATYPIC (NON-REEF-FORMING) SCLERACTINIA

Task Leader: Cairns. Other Personnel: student data entry assistants to be named (KU), support staff (Smithsonian Institution and KU). Estimated cost \$19,917.

The inventory of 1314 valid Scleractinian species, both hermatypic and ahermatypic, that Cairns has assembled (part of Cairns et al. 1999) is available in electronic format. It includes the bibliographic citation to each species. Those data can readily be "poured" into the database. However, Cairns does not have a complete list of all junior synonyms, which probably total 300 additional species for the ahermatypes (about half the scleractinian species). Some of the descriptions are in obscure publications that will take effort to locate. Cairns' major tasks are to 1) become acquainted with the capabilities of the database so he can improve it and constructively interact with people handling data entry for ahermatypes, 2) locate the original descriptions of species he does not possess, 3) provide guidance on linking of synonyms, and 4) locate subsequently published accounts of all species that provide locality data. Cairns will also provide station lists from US government cruises on which hexacorals were collected – in electronic format, when possible. Data-entry tasks will be done in Kansas. They are to 1) "pour" the existing data into the database, 2) enter into the database taxonomic, bibliographic, and locality data from the original descriptions of junior synonyms, 3) link synonyms, and 4) enter into the database additional locality data. Major clerical tasks to be done at Cairns' institution are to photocopy and send to the data-entry person 1) the original descriptions of species that are junior synonyms, and 2) literature containing locality data.

Task 5: ZOANTHIDEA

Task Leader: Ryland. Other Personnel: student to be named. Estimated cost \$30,689.

Ryland will recruit an Honours or M.Sc. student to enter bibliographic, locality, and taxonomic data as part of a biogeographic/systematic research project. The basis of the systematic inventory will be a mimeographed listing of species of most zoanthid families with relevant bibliography (Walsh 1967), which Ryland already has available as a word-processing file. This will be corrected and up-dated, and omissions will be rectified. Locality information

will have to be obtained from the original literature. Ryland and the student will come to Kansas to learn the functionalities of the database. A stipend is needed for the student, and research support for the student and Ryland.

Task 6: HERMATYPIC (REEF-FORMING) SCLERACTINIA

Task Leader: Veron. Other Personnel: support staff (AIMS and KU), databasing (B&P). Estimated cost \$9,524.

Veron has spent the past three decades inventorying hermatypic corals. From this inventory he compiled the information for his soon-to-be-published three-volume work on reef-forming corals of the world. The data underlying these volumes will be made available electronically for the first time as part of the proposed hexacoral database. Having been accumulated over considerable time, they are in various formats in several applications, some of which are no longer readily available. We will therefore have all the data parsed and translated so they can be “poured” into the Access database. This task, to be done by Bits & Parity in the Philippines, will provide an opportunity to check them and obtain from them information relevant to other parts of the database.

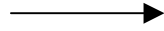
Task 7: CERANTHARIA


Task Leader: Molodtsova. Other Personnel: data entry student assistants (KU). Estimated cost \$22,885.


Of the orders yet to be included in the database, Ceriantharia has the fewest nominal species, with about 50, of which most appear valid. Because of limited computer and literature resources available at her home institution, Molodtsova will come to the US early in the project to learn the functionalities of the system and then remain to complete data entry. After she returns to Russia, Molodtsova will work mainly to assemble distributional and taxonomic data for larval cerianthids, which are large, distinctive, and abundant in some plankton tows. Although there is a substantial literature on them, few larvae have been raised through metamorphosis, so larvae have not been matched with adults, and scientific names have not been applied to them. Molodtsova will attempt to reconcile as many records as she can and, on a second trip to Kansas, will enter information on larvae into the database. These data will differ from the others in the database because they will be for the plankton rather than the benthos.

3. Overall project schedule and task timelines

Month	Task Number							Notes, Milestones, Deliverables			
	1a	1b	2a	2b	3	4	5		6	7	
1			↓								
2			↓								
3			↓								Training workshop at KU
4			↓								Synonymies module ready
5			↓								Task 7 first phase β-complete
6			↓								Task 6 data transfer
7			↓								
8		↓	↓								
9		↓	↓								(Tool design and development)
10		↓	↓								
11		↓	↓								
12		↓	↓								
13		↓	↓								(Tool test and application)
14		↓	↓								Initial bio/geo integration
15		↓	↓								Task 6 β-complete
16		↓	↓								Task 3 β-complete
17		↓	↓								Task 7 phase 2 β-complete
18		↓	↓								
19		↓	↓								Task 5 β-complete
20		↓	↓								Task 4 β-complete
21		↓	↓								Final bio/geo integration
22		↓	↓								WWW version deployed
23		↓	↓								
24	↓	↓	↓	↓							CD distribution

Light activity: planning, maintenance, follow-up (e.g. proof reading) = 

Moderate activity: ongoing search and data entry, design, and testing = 

Heavy activity: training major data transfer, integrated test, and development = 

β-complete = ready for use-testing; "final draft" version

This schedule is an estimate based on the proposed 15 May 2000 start date. Contingencies, opportunities, or changes in the start date may result in shifts of 1-2 months.

E. ANTICIPATED RESULTS FOR THE PROPOSED NOPP EFFORT

The objective of this project is to describe and understand the distribution of corals, sea anemones, and their allies, (that is, all the members of subclass Hexacorallia except order Antipatharia) by integration and analysis of appropriate taxonomic and physico-chemical data in a geospatial context. Because data on the organisms also have an historical dimension, relationships among organism distributions and environmental variables that will be used to identify habitat characteristics can be used to generalize poorly-known distributions through time as well as space. This project will provide conceptual models and tools that can be applied to other marine taxa and problems.

Knowledge of taxonomy and biogeography for most hexacorals is rudimentary, and museum records are incomplete (and potentially inaccurate), so we will obtain data primarily from the published record. The species forms the core of our database; each name is verified by reference to its publication. Our raw biogeographical datum is locality at which an individual specimen occurred (georeferenced in three dimensions, with an assessment of precision). We will abstract ranges of taxa (species, families, etc.) from such points. Analyzing distributions of physical, chemical, and environmental data important to defining habitats of these organisms against biological ranges can provide insight into abiotic factors that govern organism distribution. Overlaying ranges of multiple taxa can provide insight into biotic interactions.

Such data are useful for management, conservation, and other applications; they also contribute to understanding the functioning of marine ecosystems. We shall therefore make them accessible to as wide an audience as possible in media and forms that are as useful as possible. We plan to distribute the Access database containing taxonomic and locality data as part of the CD-ROM containing ReefBase, which will contain a compiled (stand-alone run-time) version of Access so users without the program can use the database. A website that will constitute part of OBIS will contain, in addition, the abiotic databases, tools that will allow analyses of these databases singly or interactively, and associated databases such as gazetteers.

As for the biotic, the databases for the abiotic component of this project will use metadata standards appropriate to the data and community. Analysis at various scales will be through tools of geographical information systems that are standard and widely used. The applications and tutorials we create will use macros and code designed to ensure that the products can make use of other independently-developed analytical or display tools, and can be incorporated into or linked to other OBIS products.

Underlying our analytical approach is the concept that organism distribution can be defined in "n-dimensional" space. Three spatial and one temporal dimension will be explicit in the taxonomic database. We will assemble data for other parameters that define or can be used as proxies to define distribution/biogeography, or that otherwise control potential habitat of hexacorals.

Among the tools we intend to develop will be standardized, user-friendly overlay and query analyses, with tutorials and examples based on tailored ArcView approaches, clustering and similarity analysis techniques applicable to both environmental data and organism distributions, and links or access guides for locating and using sources of data other than those specifically included in the database products. Both the tools and "how-to" instructions and examples will be available over the WWW and embedded in distributed products.

Thus, through the proposed project we will "create a design and protocol for OBIS that will allow a broad participatory process including those who obtain, manage, and/or use the data" (quote from <http://core.cast.msstate.edu/NOPP00BAA.html#topicb>) by fulfilling the three objectives enunciated in the working group report of the Organization for Economic Cooperation and Development, for we will

- Coordinate development of new software that links databases embracing a broad range of biodiversity information, including geographical and ecological;
- Digitize specimen-based biodiversity information; and
- Compile a definitive list of species, by name.

F. INSTITUTIONAL CAPABILITIES

The University of Kansas is well-suited to host and support the proposed work.

The Kansas Geological Survey (KGS) has major programs in data management and distribution, and in public information and education. It is a leader in the field of web-based dissemination of geological and resource information (www.kgs.ukans.edu), and it operates under contract the Kansas Data Access and Support Center (DASC: http://gisdasc.kgs.ukans.edu/dasc_net.html), a repository and distribution facility for GIS databases for the state of Kansas. Although its primary focus is the state, KGS and its research staff are internationally recognized, and contribute to earth science research and information in many arenas. An initiative is in progress to establish a Spatial Data Center, using DASC as a clearing house, that "...will provide access to comprehensive data for Kansas and to regional, national, and global data sources...[with a goal of]...easy access and seamless integration of data." (from a letter of intent to the National Science Foundation).

KGS maintains a suite of UNIX and Windows NT web servers, plus extensive computer and production facilities for data management (using Oracle and MS Access) and computerized cartography and geospatial data management (using Arc-Info). Including DASC, there is a staff of 12 full-time professional computer and data support personnel, and 7 positions in the relevant public information areas; these are augmented by numerous part-time and temporary employees.

KGS will support the proposed research with internal and external network administration, hardware and software access and support, workspace, administration and infrastructure, and the advantages of working in an institutional setting with active programs to develop geospatial research tools and data/information dissemination programs. A major feature of this support will be development of Oracle functionality for the database; the Access version will continue to be supported for distribution to individual users, while the Oracle version will provide reliable rapid access for centralized use and for incorporation into OBIS.

The Department of Geography, with support at the University level, is actively building a strong, broad-based program in the application of digital data to all aspects of geographic research, and has added three faculty members with GIS-related interests in the past few years. The Department's emphasis is on integration across subject areas, and across methods (e.g. GIS and remote sensing). It is the academic base for the methods and GIS students on the project, and an important source of collaboration and expertise.

The Kansas Applied Remote Sensing Laboratory (KARS: <http://www.kars.ukans.edu>) is a leader in the application of remote sensing techniques to environmental questions ranging from agricultural productivity through weather and climate to the distributions of threatened and endangered species. As the NASA Great Plains Regional Science Application Center, it carries out a wide range of research and service activities.

The KU Natural History Museum and Biodiversity Research Center (KUNHM) is a National Systematics Research Resource Center; it and its associated degree-granting departments in the KU College of Liberal Arts and Sciences constitute a Center for Education in Systematics (Association of Systematics Collections 1991). KUNHM has long provided a focal point for KU's excellent research program in systematic and evolutionary biology; its research staff members have received the greatest number of PEET grants awarded to a single institution. More recently, it has developed strong programs in bioinformatics and biodiversity (e.g. Peterson et al. 1999). Like KGS, it has an active program of public outreach and education. KUNHM will provide computer network and software support to the facilities in Fautin's lab.

The Department of Ecology and Evolutionary Biology (EEB) houses Fautin's research lab and is the academic home of the "bio" students in the project. It has an international reputation in the area of organismal biology, and provides a strong and diverse academic base for linkages to other biological specialties and applications.

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IV. Personnel: qualifications and experience

Curricula vitae for the PI, co-PI, and all key personnel are at the end of this section.

A. OVERVIEW

OCEANOGRAPHIC AND ENVIRONMENTAL EXPERTISE: Robert W. Buddemeier (Kansas Geological Survey) has served as a tenured faculty member in an oceanography department and as a member of commissions and working groups dealing with oceanic subjects. He has published extensively on the environmental correlates of coral and coral reef occurrence, growth and metabolism, and has a major role in the interdisciplinary environmental activities of the LOICZ project. Laura T. David, principal contact for the Bits & Parity institutional partner, is a Ph.D. physical oceanographer with an appointment to the Marine Science Institute of the University of the Philippines. In addition to individual expertise, the project will draw on institutional capabilities of NOAA, NCRI, and LOICZ through partnership agreements and collaborations. In addition to the LOICZ community, the last association provides linkages to the JGOFS community via the Continental Margins Task Team, a joint LOICZ-JGOFS activity. A particularly significant collaborator is J. A. Kleypas of NCAR, who is a member of the LOICZ calcification team and a key assembler and distributor of databases for the U.S. JGOFS community as well as for LOICZ. B. Maxwell (Swarthmore College) will continue to develop and coordinate the LoiczView environmental clustering software (<http://www.palantir.swarthmore.edu/~maxwell/loicz/>).

GEOGRAPHIC INFORMATION SYSTEM EXPERTISE: The staff computer specialist (Misgna) and one of the graduate students (Bartley) are both geographers who have attained a professional level of competence in GIS applications through prior work experience and training. As an undergraduate research assistant supported on an REU supplement to Fautin's PEET grant, Bartley played a major role in developing the GIS components of the existing anemone database and has already contributed significantly to LOICZ products. Misgna is working toward a Ph.D. in the use of GIS to assess and model resource management, and is currently employed to develop a broadly interdisciplinary WWW facility dealing with water and environment issues, making extensive use of GIS and visualization tools. The third graduate student to be recruited is envisioned as either a computer science information/visualization specialist or another "methods-oriented" geographer to work on interfaces and user tools.

TAXONOMIC EXPERTISE: Taxonomists are an endangered breed of scientists (e.g. Nierenberg 1999). In assembling information on a group of related organisms and providing tools to analyze some facets of the biogeography, ecology, and taxonomy, this project will make 140 person years of dedication to hexacorals available through space and time.

Antipatharia (black corals) is the only order of Hexacorallia not included in this project. The authority on these animals, Dennis Opresko, was invited to participate, but considers taxonomic knowledge of them too rudimentary for the purposes of this project (see appended letter).

Actiniaria, Corallimorpharia, and Ptychodactiaria: Daphne G. Fautin (University of Kansas).

Fautin is author or coauthor of publications such as the chapter on cnidarians for the *Encyclopedia Britannica* (Hand and Fautin 1988) and the McGraw-Hill encyclopedia of living organisms (Dunn 1982), sections on hexacorals for faunal guides and inventories (e.g. Fautin et al. 1987, Fautin 1998, Fautin and Hand submitted), and pages on Cnidaria for the Tree of Life (Fautin and Romano 1997, 1999; Fautin et al. 1999). She has received two grants in the PEET program to study and train students in the study of sea anemone systematics.

Scleractinia: Stephen D. Cairns (National Museum of Natural History, USA) and J. E. N. Veron (Australian Institute of Marine Science).

Cairns is organizer of the Cnidaria and Ctenophora list of the American Fisheries Society (Cairns et al. 1991), and co-coordinator of the Tree of Life pages on Cnidaria, coauthor of the list of extant stony corals of the world (Cairns et al. 1999), and inventories of non-reef-forming corals of many parts of the world (e.g. Cairns 1991, 1994). Cairns is also part of the PEET grant "Collaborative research: Monographic studies of the Hydractinioidea" (1999-2003).

Veron is author and co-author of definitive treatises on taxonomy, systematics, biogeography, paleontology, ecology, and evolution of reef-forming corals. His primary achievements have been to 1) create a stable taxonomy of corals now used throughout the Indo-Pacific, 2) monograph the global distributions of coral (e.g. Veron 1986, 1992, 1999; Veron and Marsh 1988), 3) propose mechanisms of coral evolution and maintenance of species diversity (Veron 1995), and 4) create an information base for reef conservation and management.

Zoanthidea: John S. Ryland (University of Wales Swansea, UK)

Ryland is an experienced taxonomist, and coeditor and major contributor to the definitive *Marine Fauna of the British Isles and North-West Europe* (Hayward and Ryland 1990). He is author or coauthor of sections on zoanthids in *A Coral Reef Handbook* (Ryland and Muirhead 1993) and in field guides to the marine fauna of Bermuda and of East Africa, and of papers on taxonomy and reproduction of zoanthids (e.g. Babcock and Ryland 1990, Burnett et al. 1997, Ryland 1997).

Ceriantharia: Tina N. Molodtsova (P. P. Shirshov Institute of Oceanology of the Russian Academy of Science).

Molodtsova has very nearly completed her Ph.D. degree in the Department of Invertebrate Zoology, Moscow State University with a dissertation entitled "Faunae of cerianthids of the Atlantic Ocean and composition of the genus *Cerianthus*." She is the only active taxonomist of this group in the world, to our knowledge.

Computerization of taxonomic information: Adorian Ardelean (University of Kansas, USA)

Ardelean is a Romanian Ph.D. student working with Fautin on revision of sea anemone family Actinodendridae. He currently is supported on a PEET grant. He has developed a powerful and original application for presentation of information on synonymous names (see above) that is central to retrieving all records for a species and for graphic display of this information.

B. COOPERATING ORGANIZATIONS

Land-Ocean Interactions in the Coastal Zone (LOICZ) programme element of the International Geosphere Biosphere Programme (IGBP)

LOICZ endorses the effort (see appended letter), will make available and coordinate presentation and analysis of its Typology and Biogeochemical Budget databases, and has further committed to supply a minimum of \$10-20k/year (exact amount to be determined) for the coordinated environmental typology work. In addition, LOICZ has a major contract with the Global Environmental Facility (GEF) of the UN Environment Programme (UNEP) to engage scientists from developing countries in a coordinated project to regionalize and then globalize coastal zone biogeochemical budgets, using a typologic approach. This project, to conclude in 2001, will be closely coordinated with the proposed research. This coordination will result in mutual economies, greatly expanded exposure and dissemination of the products and techniques, and a wide range of rapid applications of the products. Buddemeier has significant ongoing involvement in both the overall LOICZ typology effort and the GEF project.

International Center for Living Aquatic Resource Management (ICLARM)

John McManus, director of the ReefBase Project, supports and is interested in cooperation with the proposed activities (see appended letter). He had previously offered to distribute both Fautin's sea anemone database and Veron's reef-forming corals database as part of ReefBase CDs. The integrated database we propose will be an even more valuable adjunct to ReefBase, an ecosystem-level distributional database, for it will provide species-level biogeographic and taxonomic information about important reef formers and inhabitants. ReefBase might eventually assume operation and maintenance of the proposed database in the event the project and products grow beyond the capabilities and interests of the University of Kansas.

Bits & Parity

Bits & Parity, a computer consulting agency based in Manila, Philippines, specializes in database creation and conversion. Projects include, but are not limited to, database creation and maintenance of higher learning library resources, conducting seminars and workshops on database management using training modules developed in-house, and documentation and archiving of conference proceedings or entire company files. The agency has developed CABARET, a user-friendly biogeochemical budgeting package, for distribution by LOICZ, and will contribute to the assembly of the second-generation LOICZ Typology database. The company

is closely associated with the University of the Philippines and its Marine Science Institute, providing access to subject area as well as computer expertise. The agency will extract the relevant data from Veron's databases on hermatypic corals, which are now in a variety of applications, and convert them to formats suitable for incorporation into the proposed database.

The National Coral Reef Institute

Located at Nova Southeastern University, NCRI (<http://www.nova.edu/ocean/ncri/>) promotes research on high-leverage, cutting-edge topics that address issues of coral reef vulnerability, biodiversity and management, with the ultimate objective of informed prioritization of research and conservation efforts. They currently support the co-PI with a \$35,000 contract for development of electronic databases and tools for the assessment of coral reef biodiversity and vulnerability. The participation of NCRI, which enthusiastically supports the proposed research (see attached letter), provides synergistic funding for compatible databases, tools, and applications that permit this Census of Marine Life proposal to build on existing initiatives rather than duplicating effort.

BIOGRAPHICAL SKETCH of DAPHNE GAIL FAUTIN

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Positions held:

University of Kansas, Lawrence, Kansas

Department of Ecology and Evolutionary Biology (formerly Systematics and Ecology)

Professor September 1995-present

Adjunct Professor December 1989-September 1995

Department of Entomology

Professor October 1995-present

Adjunct Professor September 1991-October 1995

KU Natural History Museum

Curator September 1995-present

Adjunct Senior Scientist December 1989-September 1995

Kansas Geological Survey

Adjunct Senior Scientist December 1989-present

California Academy of Sciences, San Francisco, California

Department of Invertebrate Zoology

Curator July 1989-January 1990

Associate Curator July 1984-June 1989

Assistant Curator July 1980-June 1984

Research Biologist/Associate October 1975-June 1980, January 1990-present

Education:

Ph.D. (zoology) 1972 University of California, Berkeley, California

B.S. (biology) Magna Cum Laude 1966 Beloit College, Beloit, Wisconsin

Professional service (selected):

Annual Review of Ecology and Systematics Editor, 1992-present

International Society for Reef Studies Treasurer, 1992-present

Sigma Xi, University of Kansas Chapter Treasurer 1998 - present

Society for Integrative and Comparative Biology Division of Systematic Zoology, Program Officer, 1990-1991; Division of Invertebrate Zoology, Chair, 1997-1999

Society of Systematic Biologists Councillor, class of 1990, class of 2001

Grants related to proposal:

National Science Foundation Grant DEB-9521819 (PEET program), September 1995 - September 2000:

“Inventory, systematics, and phylogeny of sea anemones: Training of modern systematists and electronic dissemination of data.”

Research Experience for Undergraduates supplement to DEB-9521819, May 1999 – May 2000

Research Experience for Undergraduates supplement to DEB-9521819 in a special competition in bioinformatics, May 1998 – May 1999

National Science Foundation Grant DEB-9978106 (PEET program), September 2000 - September 2005: “Sea anemone systematics: consolidation and synthesis of information” (approved but not yet awarded)

Five publications most closely related to proposed research:

Buddemeier, R. W. and D. G. Fautin. 1996. Saturation state and the evolution and biogeography of symbiotic calcification. *Bulletin de l'Institut Océanographique, Monaco special number 14(4)*: 23-32.

Fautin, D. G. 1989. Anthozoan dominated benthic environments. *Proceedings of the Sixth International Coral Reef Symposium 3*: 231-236.

- Fautin, D. G. 1999. Sea anemones of the world: catalogue of species, bibliography of literature in which they were described, and inventory of existing type specimens. Version 2.0. <http://biocomplexity.nhm.ukans.edu/anemones/images/Version.html>
- Fautin, D. G. and G. R. Allen. 1992. Field guide to anemonefishes and their host sea anemones. Western Australian Museum. 160 pages. [electronic version <http://www.keil.ukans.edu/ebooks/intro.html>] [Reprinted 1994 in English as *Anemone fishes and their host sea anemones*, TetraSales, Blacksburg, Virginia; and in German as *Anemonenfische und ihre Wirte*, Tetra-Verlag, Melle]
- Fautin, D. G. and J. M. Lowenstein. 1994. Phylogenetic relationships among scleractinians, actiniarians, and corallimorpharians (Coelenterata: Anthozoa). *Proceedings of the Seventh International Coral Reef Symposium* 2:665-670.

Five other related publications:

- Buddemeier, R. W. and D. G. Fautin. 1996. Global CO₂ and evolution among the Scleractinia. *Bulletin de l'Institut Océanographique, Monaco special number* 14(4): 33-38.
- Dunn, D. F. 1981. The clownfish sea anemones: Stichodactylidae (Coelenterata: Actiniaria) and other sea anemones symbiotic with pomacentrid fishes. *Transactions of the American Philosophical Society* 71(1): 1-115.
- Fautin, D. G. 1998. Class Anthozoa: Orders Actiniaria, Ceriantharia, and Zoanthinaria. *Taxonomic Atlas of the Benthic Fauna of the Santa Maria Basin and Western Santa Barbara Channel, vol. 3 (The Cnidaria)*, pp. 113-139, P. V. Scott and J. A. Blake, eds. Santa Barbara Museum of Natural History, Santa Barbara.
- Fautin, D. G. and R. N. Mariscal. 1991. Cnidaria: Anthozoa. *Microscopic Anatomy of Invertebrates, vol. 2*, pp. 267-358 F.G. Harrison and J.A. Westfall, eds. Liss, New York City.
- Fautin, D. G. and Brian R. Barber. 1999. *Maractis rimicarivora*, a new genus and species of sea anemone (Cnidaria: Anthozoa: Actiniaria: Actinostolidae) from an Atlantic hydrothermal vent. *Proceedings of the Biological Society of Washington* 112(3): 624-631.

Collaborators during past 48 months

- Kelvin Berryman (Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand)
- Robert W. Buddemeier (Kansas Geological Survey, Lawrence)
- Stephen D. Cairns (U. S. National Museum of Natural History)
- Colin P. Chilcott, Robert Pearce, Terence P. Scoffin, and Alexander W. Tudhope (Department of Geology and Geophysics, Edinburgh University)
- Jonathan Geller (Moss Landing Marine Laboratory, Moss Landing)
- Cadet Hand (Bodega Marine Laboratory, Bodega Bay)
- Chau-Chih Guo and Jiang-Shiou Hwang (National Ocean University, Taiwan)
- Matthew Jebb (National Botanic Gardens, Dublin)
- Jere H. Lipps (Museum of Paleontology, University of California, Berkeley)
- April Wakefield Pagels (Kansas City, Kansas)
- Sandra Romano (University of Guam Marine Laboratory, Mangilao)
- Graham B. Shimmiel (Dunstaffnage Marine Laboratory, Oban, Argyll)
- Deborah R. Smith (Department of Entomology, University of Kansas)
- John R. Ware (SeaServices, Inc., Gaithersburg, Maryland)

Graduate students and Post-Doctoral Fellow

- Post-doctoral fellow: Valerie Cappola
- KU Graduate students: Adorian Ardelean, Susanne Hauswaldt, Katherine E. Pearson, April Wakefield Pagels, Tracy R. White
- Graduate students other than KU: Robin Eppard (University of Nevada, Reno), Chau-Chih Guo (Taiwan National Ocean University), Steven E. Wedi (San Francisco State University)

Advisors

- Ph.D. Cadet Hand (Bodega Marine Laboratory, Bodega Bay, California) (retired)
- Post-doctoral Ted R. Norton (Burns School of Medicine, University of Hawaii) (retired)

BIOGRAPHICAL SKETCH

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Education:

University of Washington (Seattle) Ph.D., Chemistry, 1969; dissertation topic, "A Radiocarbon Study of the Varved Marine Sediments of Saanich Inlet, British Columbia"
University of Illinois, Urbana, B.S., Chemistry, 1958

Professional Employment Record:

- University of Kansas, 1990-present: Senior Scientist, Kansas Geological Survey. Also: Chief, Geohydrology Section, KGS, 1990-95; Courtesy Professor, Dept. of Geography, 1991-present:
- Lawrence Livermore National Laboratory, Livermore, CA: Chemist, Environmental Sciences and Geochemistry Group, Nuclear Chemistry Division, 1979–1990. Also: Assoc. Division Leader for Environmental Projects, 1989-90; Group Leader and Project Leader
- University of Hawaii (Manoa), and Hawaii Institute of Geophysics (HIG), 1969-79: Assoc. Prof., Dept. of Oceanography, 1974-79; Asst. Prof., Dept. of Oceanography 1973-74. Asst. Prof., Dept. of Chemistry, 1969-72.
- University of Washington Chemistry Dept.: Predoctoral fellow, 1965-69; Instructor 1969; Staff Chemist, 1962-1965.

Society Memberships:

(1) American Geophysical Union (2) American Association for the Advancement of Science (3) Pacific Science Association (4) International Society for Reef Studies (5) Soil and Water Conservation Society (6) Kansas Academy of Science (7) Association of American Geographers (8) Society for Integrative and Comparative Biology

Appointments:

- Focus Leader, Scientific Steering Committee of the Land-Ocean Interactions in the Coastal Zone (LOICZ) Core Project of the International Geosphere-Biosphere Programme, 1996-2001.
- Visiting Senior Scientist, LOICZ Core Project Office, Texel, The Netherlands, 1996.
- Chairman, SCOR (Scientific Committee on Oceanic Research)/LOICZ Working Group 104: Coral Reefs Responses to Global Change: the Role of Adaptation, 1994-1999.
- Member, SCOR/LOICZ Working Group 112: Magnitude of Submarine Groundwater Discharge and its Influence on Coastal Oceanographic Processes, 1998-2002
- Member, IUCN (World Conservation Union) Commission on Ecology, 1992-93
- Member, Global Task Team on Coral Reefs and Climate Change (IOC, UNEP, ASPEI, IUCN), 1992-94.
- Fellow, California Academy of Sciences, San Francisco, CA (elected 1989).
- Director, Zone 7 Alameda County Flood Control and Water Conservation District (nonpartisan elected position), 1984-88; Chairman, Board of Directors, 1985-86.
- Visiting Research Scientist, Australian Institute of Marine Science (Townsville), July-August, 1988 and January-April 1983.
- Visiting Scientist, Romberg Tiburon Center for Environmental Studies (Tiburon, CA), December 1987 - August 1988.
- Fellow, Christensen Research Institute (Madang, Papua New Guinea), August-November, 1987.

Current research interests:

System-level responses to environmental change; characterization of environments and environmental transitions at various temporal and spatial scales; interactions of climate and direct anthropogenic changes; sustainability and resource use; acclimation and adaptation at community and organism level; integration of natural and social science data and models.

Closely related publications:

Buddemeier, R. W., and Smith, S. V. 1999. Coral Adaptation and Acclimatization: A Most Ingenious Paradox. *American Zoologist* 39(1):1-9.

Kleypas, J. A., Buddemeier, R. W., Archer, D., Jean-Pierre Gattuso, J.-P., Langdon, C., and Opdyke, B. N. 1999. Geochemical Consequences of Increased Atmospheric CO₂ on Coral Reefs. *Science* 284:118-120.

Buddemeier, R. W., Fautin, D. G., and Ware, J. R. 1997. Acclimation, Adaptation, and Algal Symbiosis in Reef-Building Scleractinian Corals. pp. 71-76 in: den Hartog, J. C. (ed.), *Proceedings of the 6th International Conference on Coelenterate Biology*, National Museum of Natural History, Leiden.

Wilkinson, C. R. and Buddemeier, R. W., 1994. *Global Climate Change and Coral Reefs: Implications for People and Reefs*. Report of the UNEP-IOC-ASPEI-IUCN Global Task Team on the Implications of Climate Change on Coral Reefs. IUCN, Gland, Switzerland. 124 pp.

Smith, S. V., and Buddemeier, R. W., 1992. Global change and coral reef ecosystems. *Annual Reviews of Ecology and Systematics* 23:89-118.

Other relevant publications:

Buddemeier, R. W. and Fautin, D. G. 1996. Global CO₂ and Evolution among the Scleractinia. In: Allemand, D. and Cuif, J.-P. (Eds.) *Biom mineralization 93, Proc. 7th Int. Symp. on Biom mineralization*. Bulletin de l'Institut océanographique, Monaco, Numero spécial 14,4. pp. 33-38.

Buddemeier, R. W. and Fautin, D. G. 1996. Saturation State and the Evolution and Biogeography of Symbiotic Calcification. In: Allemand, D. and Cuif, J.-P. (Eds.) *Biom mineralization 93, Proc. 7th Int. Symp. on Biom mineralization*. Bulletin de l'Institut océanographique, Monaco, Numero spécial 14,4. pp. 23-32.

Buddemeier, R. W., and Fautin, D. G. 1993. Coral Bleaching as an Adaptive Mechanism: A Testable Hypothesis. *BioScience* 43:320-326.

Buddemeier, R. W., 1991. Climate Change and Biology: A Proposal for Scientific Impact Assessment and Response, pp 161-169 in Dudley, E. C. (ed), *The Unity of Evolutionary Biology*, Vol. 1, Discorides Press, Portland, Or.

Buddemeier, R. W., and Hopley, D., 1988. Turn-ons and Turn-offs: Causes and Mechanisms of the Initiation and Termination of Coral Reef Growth, in *Proc. Sixth Int. Coral Reef Symp.*, J. H. Choate et al. (eds), Vol. 1, pp. 253-261.

Collaborators, past 48 months (PhD-level only named -- also students and support staff from the same institutions): R. A. Kinzie, H. Rubin, F. W. Taylor, J. A. Oberdorfer, M. A. Sophocleous, P. A. Macfarlane, D. G. Fautin, D. O. Whittemore, J. R. Ware, S. V. Smith, J. A. Kleypas, B. N. Opdyke, J.-P. Gattuso, C. Crossland,

Students/Postdocs (5 years): No postdocs, committee member for 2 PhD students (A. Arbogast, R. Sleezer); primary advisor of three MS students (G. Garneau, J. Bartley, J. Artman) and committee member for 3 others.

Graduate advisor: A. W. Fairhall (deceased). No postdoc.

Curriculum Vitae of Adorian Ardelean

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Lawrence, KS 66045 USA
E-mail: adorian@eagle.cc.ukans.edu
Telephone: (785) 864-4607 Fax: (785) 864-5321

Place of Birth: Timisoara, ROMANIA.
Nationality: Romanian

Education:

1989 - Baccalaureate degree in Chemistry-Biology, (Liceul de Filologie-Istorie)
1990-1995: University education in general Biology, at the West University of Timisoara
1995 - Licence in Biology; Thesis: Aspects of the Morphology and Behavior in *Actinia equina*.
1996 -1998 Doctoral student at Babes-Bolyai University of Cluj-Napoca (Department of Biology)
1998 - present Graduate student at University of Kansas (Ph.D); Thesis subject: Revision of the family Actinodendridae.

Professional Employment:

Teaching Assistant - Faculty of Chemistry-Biology-Geography, Department of Biology (West University of Timisoara)
-1995-1998: Invertebrate Zoology
-1996-1997: The Gathering, Preservation and Preparation of Biological Material.
Research Assistantships: Under Dr. D. Fautin's Partnerships for Enhancing Expertise in Taxonomy (PEET), 1998 and 1999.

Languages, in order of fluency:

Romanian (native language); English (reading, talking and writing ability); German (reading ability); French (reading ability).

Publications:

Ardelean A. (1996) - Aspects Regarding the Approach of Comportamental Investigations in *Actinia equina* (Anthozoa). *Annals of the University of Timisoara, Seria Biologie*, vol 1, 1996.
Ardelean A. (1996) - Locomotion Keyframes in *Actinia equina* (Anthozoa). *Annals of the University of Timisoara, Seria Biologie*, vol 1, 1996.
Ardelean A. (1998) - Anthozoa Encyclopaedia (alpha Version) a Multimedia Database about Sea Anemones and Corals. The 2nd International Symposium Interdisciplinary Zonal Research, December 11 - 12 1997, Timisoara, România.
Ardelean A., and Trandafir G. (1999) – Black Sea Invertebrates. <http://cbg.uvt.ro/~adorian/blackseaguide/indexulspeciilor.htm>

Invited Talks & Workshops:

Ardelean A. (May 22, 1997) - Computer Analysis of Behavioural Links. Academic Days of Timisoara, Romanian Academy, branch Timisoara.
Fautin D.G., Bartley J., Henning J., Fullerton M.D., and Ardelean A. (November 3-4, 1999) - An Electronic Atlas of Sea Anemones. Ocean Biogeographical Information Systems (OBIS), Washington, D.C.

Posters:

Ardelean A. (December 12,1997) - Anthozoa Encyclopaedia. The 2nd International Symposium Interdisciplinary Zonal Research, Romanian Ministry of Research and Technology & Romanian Academy Timisoara Branch Office.
Fautin D.G., Fullerton M.D., Bartley J., and Ardelean A. (November 18, 1999) - Sea Anemone Distributions and their Environmental Correlates. Land-Ocean Interactions in the Coastal Zone Fourth Open Science Meeting, Bahia Blanca, Argentina.

Main Software developed for specific use:

Saprodata - a simple, but very efficient program for sprobity index calculation (1996)
Sycon - presentation program for syconoid structural type - 3D (Porifera) (1996)
Sequenzdiagramm - event-recording for behavioural studies (1996-1997)
BioData Taxonomic Manager - (1996 -...)

Computer Skills:

PC Operating Systems: Windows'95, Windows 3.1, MS-DOS
Languages: Visual Basic 6, HTML.
Word Processors: Page Maker 6, Word for Windows 95.
Computer-assisted illustration: Adobe PhotoShop 4, Fractal Design Painter 3
3D Animation & Reconstruction: 3D Studio, Vista Pro 3, VoxBlast.
Other software: LucID Professional, MacClade, Specify.

Professional Affiliations:

Associate Member of The Linnean Society of London.
Graduate Student Member of Society for Integrative and Comparative Biology (SICB).
American Microscopical Society (AMS).
Member in Redactional Committee for Annals of the University of Timisoara (România)
Editor of Annals of the University of Timisoara (România).

Curriculum vitae: Jeremy D. Bartley

Kansas Geological Survey
1930 Constant Ave (785) 864-3965
Lawrence, Kansas 66047 jbartley@kgs.ukans.edu

Education

B.S. (Geography), University of Kansas, 1999
Graduate study (Geography), University of Kansas, 1999 -present

Professional Experience

Kansas Geological Survey: Graduate Research Assistant, August 1999-present
(duties: create and disseminate an electronic database of basic environmental and climatic information related to the vulnerability of reefs and reef habitats to global change.)
University of Kansas Department of Ecology and Evolutionary Biology: Undergraduate Research Assistant, May 1998-May 1999
(duties: design and integrate a geographic analysis module for database on sea anemone biodiversity; replicate the geographical database component so that it would be accessible from the Internet.)
University of Kansas Natural History Museum: Research Assistant, November 1997-August 1999
(duties: Collect climate and other environmental data for Mexico; acquire and apply climate change scenarios to current weather patterns; develop regional climate and vegetation change scenarios.)
USDA Natural Resource Conservation Service, Lawrence, KS: Cartographic Aide (GS-03) 1997-April 1998
(duties: Participated in the development of a hydrography layer from digital orthophotos; classified landuse/landcover areas in riparian buffer zones; developed a database management system and a project metadata under FGDC standards. Served as Acting Cartographer (GS-07) November 1997-February 1998; trained and supervised three cartographic aides.)
Transpar Group Overland Park, KS: GIS Technician, 1996
Edited TIGER files and student database files for a school bus routing company.

Professional Qualifications and Related Experience

Computer Experience: Systems: PC, UNIX, Macintosh; Operating Systems: Windows 98, Windows NT, SunOS;
Software: Arc/Info 7.21 (familiar with all modules), ArcView 3.2 (familiar with all extensions), MapInfo 4.0, Surfer 6.04, Erdas Imagine 8.3, SPSS 7.5, Freehand 8.0, Microsoft Office 98; Programming Languages: MapObjects 1.2, Visual Basic 6.0, C/C++, Delphi 4.0, Digital Fortran, HTML
Volunteer Experience: Prepared databases and maps of coastline complexity, coastal climate change scenarios, and coastal zone classifications for the LOICZ project of the International Geosphere-Biosphere Programme; helped create maps of the Oregon and Santa Fe Trail for the City of Lawrence Visitor's guide.

Professional Associations

American Association for the Advancement of Science
Association of American Geographers

Publications and presentations:

Bartley, Jeremy D. The Classification and Use of Coastline Complexity in the LOICZ Typology Framework. LOICZ 4th Open Science Meeting. Programme and Abstracts. Land-Ocean Interactions in the Coastal Zone, Bahia Blanca, Argentina.
Buddemeier, R. W., J. D. Bartley, and J. A. Kleypas. 1999. Coral Reefs and Calcification: A Predictive Typology. LOICZ 4th Open Science Meeting. Programme and Abstracts. Land-Ocean Interactions in the Coastal Zone, Bahia Blanca, Argentina.
Fautin, Daphne G., M. David Fullerton, Jeremy Bartley, and Adorian Ardelean. 1999. Sea Anemone Distributions and their Environmental Correlates. LOICZ 4th Open Science Meeting. Programme and Abstracts. Land-Ocean Interactions in the Coastal Zone, Bahia Blanca, Argentina.
Artman, Joshua C. and Jeremy D. Bartley A Comparison of Using Higher vs. Lower Spatial Resolution Data Sets for predicting Regional-Scale Distribution of Potential Vegetation. LOICZ 4th Open Science Meeting. Programme and Abstracts. Land-Ocean Interactions in the Coastal Zone, Bahia Blanca, Argentina.

CURRICULUM VITAE of Stephen Douglas Cairns

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FAX: 202-357-3043
e-mail: cairns.stephen@nmnh.si.edu

HOME ADDRESS:

11528 Daffodil Lane, Silver Spring, MD 20902
Tel. (301) 649-4053

EDUCATION:

B.S., 1971. Louisiana State University in New Orleans (Biology).
M.S., 1973. University of Miami, Rosenstiel School of Marine and Atmospheric Science (Biological Oceanography).
Ph.D., 1976. University of Miami, Rosenstiel School of Marine and Atmospheric Science (Biological Oceanography).

FELLOWSHIPS, GRANTS, AND POSITIONS:

Co-PI of NSF P.E.E.T grant (\$750,000) to train hydroid taxonomists (Sept. 1999- August 2004)
Curator, Department of Invertebrate Zoology, Smithsonian Institution (1991-present); Associate Curator (1985-1991); Division Supervisor (1987-1990).
Research Associate, Department of Invertebrate Zoology, Smithsonian Institution (April 1979-Feb. 1985).
Recipient of NSF grant (\$78,448) to continue research on stylasterid corals (May 1983-Feb. 1985).
Recipient of Fluid Research Grant (\$2500) from Smithsonian Institution to study early evolution of stylasterid corals (April 1983).
Team Leader of ADP project to inventory fossil coral collection of USNM (Dec. 1982-March 1983).
Recipient of NSF grant (\$24,573) to work on a cladistic revision of stylasterid genera (June 1982-Nov. 1982).
Smithsonian Postdoctoral Fellow (June 1981-May 1982).
Recipient of grant (\$11,000) from Smithsonian Oceanographic Sorting Center to work on Antarctic Stylasterina (June 1980-March 1981).
Zoologist, National Systematics Laboratory, NMFS, NOAA, Washington, D. C. (Dec. 1979-May 1980).
Recipient of grant (\$10,000) from Smithsonian Oceanographic Sorting Center to work on Antarctic Scleractinia (Dec. 1978-Sept. 1979).
Postdoctoral Research Associate, RSMAS, University of Miami. Research done at National Museum of Natural History, Smithsonian Institution (Sept. 1976-Nov. 1978).
National Science Foundation Graduate Fellow at University of Miami, RSMAS (Sept. 1971-June 1974).
ROF grants (1981, 1982, 1988, 1991 (2), 1994, 1996, 1999); CCRE grants (1978, 1985).

PROFESSIONAL SOCIETIES AND OFFICES HELD:

Biological Society of Washington (Member: 1976-present; Councillor: 1980, 1987-89, 1992-93; President-elect: 1994-6; President: 1996-present).
International Association for the Study of Fossil Cnidaria (Member: 1980-present; organizing committee and editorial board of Fourth International Symposium, 1983).
Paleontological Research Institute (Member: 1980-present).
Willi Hennig Society (Member: 1985-86).
Hydrozoan Zoologists Association (Charter Member: 1985-present).
International Society for Reef Studies (Member: 1985-86, 1994-present).
American Association for Zoological Nomenclature (Member and councillor: 1992-present).

PUBLIC SERVICE AND SCIENTIFIC EDITING:

Member, Committee on Common and Scientific Names of Aquatic Invertebrates from the United States and Canada (1987-present).
Frequent identifications of confiscated stony corals for U.S. Fish and Wildlife Service (1988-present).
Associate Editor, Proceedings of the Biological Society of Washington (1988-1991).
Associate Editor, Antarctic Research Series (1990-1995).
Associate Editor, Atoll Research Bulletin (1994-present).

ACADEMIC SERVICE:

Post-doctoral advisor to:

Elizabeth Chornesky (1985)
Esther Peters (1986)
Bert Hoeksema (1990)
Sandra Romano (1995)
Jaroslaw Stolarski (1999)

Ph.D. Committees:

Joan Owens (GWU, 1981-83)
Jaren Horesley (GWU, 1989)
Stephen Jameson (U. of Maryland, 1985-94)
B. Hoeksema (Rijksuniversiteit Leiden, 1990, Honors Committee).

M.S. Committee:

Tim Werner (U. of Maryland, 1994-1996) co-advisor
Deborah Danaher (U. of Maryland, 1993-present) co-advisor

Intern Advisor to:

Veronica Toral (1994, 2 weeks)
Veronica Vasquez (1995, 3 weeks)
Forest Gahn (1996, 10 weeks)
Noah Feinstein (1997, 10 weeks)

Adjunct Professor: University of Maryland, MEES Graduate Program (1995-present).
University of Miami (RSMAS) 1998-present

RESEARCH INTERESTS:

Taxonomy, zoogeography, functional morphology, mineralogy, and evolution of the Stylasteridae (Hydrozoa: "hydrocorals") and Scleractinia (Anthozoa).

Selected References

- Cairns, S. D. 1979. The Deep-Water Scleractinia of the Caribbean and Adjacent Waters. Studies on the Fauna of Curaçao and Other Caribbean Islands, 57(180):341 pages, 40 plates, 60 maps.
- Cairns, S. D. 1982. Antarctic and Subantarctic Scleractinia. Antarctic Research Series, 34(1):74 pages, 18 plates, 14 maps.
- Cairns, S. D. 1989a. A Revision of the Ahermatypic Scleractinia of the Philippine Islands and Adjacent Waters, Part 1: Fungiacyathidae, Micrabaciidae, Turbinoliinae, Guyniidae, and Flabellidae. Smithsonian Contributions to Zoology, 486:136 pages, 42 plates, 3 figures.
- Cairns, S. D. 1991. Catalog of the Type Specimens of Stony Corals (Milleporidae, Stylasteridae, Scleractinia) in the National Museum of Natural History. Smithsonian Contributions to Zoology, 514:59 pages.
- Cairns, S. D. 1991. The Marine Fauna of New Zealand: Stylasteridae (Cnidaria: Hydrozoa). New Zealand Oceanographic Institute Memoir, 98:179 pages, including 77 plates.
- Cairns, S. D. 1994. Scleractinia of the Temperate North Pacific. Smithsonian Contributions to Zoology, 557:150 pages, 42 plates, 3 figures.
- Cairns, S. D. 1995. The Marine Fauna of New Zealand: Scleractinia (Cnidaria: Anthozoa). New Zealand Oceanographic Institute Memoir, 103:210 pages, 44 plates, 22 maps.
- Cairns, S. D. 1999b. Species Richness of Recent Scleractinia. Atoll Research Bulletin, 459:12 pages, 1 figure.
- Cairns, S. D. and S. A. Parker 1992. Review of the Recent Scleractinia (Stony Corals) of South Australia, Victoria and Tasmania. Records of the South Australian Museum, Monograph Series, 3:82 pages, 18 plates, 3 figures, 19 maps.
- Cairns, S. D. B. W. Hoeksema J. van der Land 1999. Appendix: List of Extant Stony Corals. Atoll Research Bulletin, 459:13-46.

RESUME
GIRMAY MEHARI MISGNA

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EDUCATION

- ◆ **Ph.D. student**, Geography Department, University of Kansas, Lawrence, Kansas
August 1998 to present, Specializing in GIS and Remote Sensing.
- ◆ **Ph.D. student**, Geography Department, Southern Illinois University at Carbondale, Illinois
February 1997 to August 1998, GPA 4.0.
- ◆ **M Sc. student**, Geography Department, Southern Illinois University at Carbondale, Illinois
August 1996 to January 1997, GPA 4.0.
- ◆ **M Sc. Applied Geology**, Addis Ababa University, Addis Ababa, Ethiopia, 1990
Thesis: "Engineering Geological Mapping of Omorate Area [Ethiopia]."
Specializing in Hydrogeology and Engineering Geology.
- ◆ **B Sc. Geology**, Addis Ababa University, Addis Ababa, Ethiopia, 1987.

EXPERIENCE

- ◆ **Graduate Research Assistant**, University of Kansas Geography Department, August 1998 to May 1999. Integrated the Agricultural Non-Point Source Pollution model (AGNPS is a watershed simulation model) and GEOMINOS (a linear optimization model) into a GIS software package. This software system is used to analyze the economic and environmental impact of alternative agricultural policies in southern Illinois. The associated code was written using Avenue and Visual C++; linkages among software packages were made via dynamic link library modules.
- ◆ **Summer Research grant**, Pontikes Center in the Department of Business and Management Administration, SIUC, June 1998- August 1998. Research title "Integration of GIS and Analytic Hierarchic Process for constrained optimization problem." Used Avenue and AML scripts in an Arcview/ARCINFO application environment to integrate multi-criteria evaluation tools into GIS software. This system was used to implement alternative location allocation models for the analysis of health care services in southern Illinois. Presented result at the 1998 Great Plains/Rocky Mountain division of AAG annual meeting in the University of Kansas.
- ◆ **Research Assistant**, Environmental and Spatial Analysis Laboratory (SEAL), SIUC, Jan 1998- May 1998. Assisted in the administration of the SEAL. This GIS laboratory was equipped with: (1) four Sun Sparc UNIX workstations, one AIX UNIX workstation, and four Windows NT workstations; (2) a full complement of peripheral devices including plotter, digitizing tables, printers, and scanner; and (3) state of the art GIS and image processing software packages including, ARC/INFO, Arc-View, ERDAS-Imagine, and other MS-Windows productivity tools.
- ◆ **Research Assistant**, "Demonstrating the Analytical Utility of GIS for Policing", SIUC, Aug 1997- Dec-1997. Customized Arcview for use in crime analysis. The associated code written using Avenue script.

- ◆ **Research Assistant**, “Cache River Ecosystem Function and Restoration”, SIUC, May1997-Aug1997. Generated physical and environmental databases in Arc/Info to support the AGNPS model in UNIX environment. Conducted analysis of the results of simulation on a Cache river basin of Illinois.
- ◆ **Teaching Assistant**, World Geography, SIUC, Aug 1996-May 1997.
- ◆ **Hydrogeologist**, Tigray Development Agency, Mekele, Ethiopia, Dec 1994-Jul 1996. Prepared, designed and implemented rural water supply projects and programs of spring protection, bore hole drilling, and hand-dug well construction through community participation in several rural areas of Ethiopia. ,Conducted research on the appropriate technological approach of recharging traditional rural water supply sources by building sand storage and recharge dams across natural drainage. Designed and implemented small-scale irrigation schemes. Recruited, trained and supervised water technicians for the implementation of rural water supply projects including assessment of water supply sources.
- ◆ **Physical planning researcher**, National Urban Planning Institute, Addis Ababa, Ethiopia, Sep 1987-Dec 1994. As a member of multidisciplinary teams, I participated in the design of Master and Development plans for several towns in Ethiopia. Tasks included: (1) site selection for different types of urban land uses in terms of geological site conditions presented as hazards or opportunities; (2) land evaluation in relation to foundation conditions, drainage, and urban waste disposal; (3) assessment of available sources of water supplies amount and quality; (4) assessment of locally available building and construction materials; (5) preparation, compilation, and interpretation of engineering and hydrogeological information and map for urban and regional planning purposes.

COMPUTER SKILLS

- ◆ **Software:**
 - GIS-** ARC/INFO, Arc-View.
 - Remote Sensing-** IDRISI, ERDAS Imagine.
 - DBMS-** MS-Access, Oracle, SQL.
 - Others-** MS-Word, MS-Excel, MS-Power point, Adobe Photo-shop, PDP++ Neural Networks, MS-Front page.
- ◆ **Programming:** C, C++, Visual C++, Visual Basic, AML script, Avenue script, MapObjects, HTML.
- ◆ **Operating systems:** DOS, Windows 95, Windows NT, and UNIX

CURRICULUM VITAE

Personal: **Molodtsova, Tina N.**, 9-1, Obolenskiy pereulok #36, Moscow 119021 Russia, tel. 007 (095) 262-27-86.

E-mail: tina@ecosys.sio.rssi.ru; tnmolodtsova@yahoo.com

Born in the USSR, Vladivostok 20.12.1972; married

Education

PhD (zoology) Moscow State University, Moscow, 1999. Dissertation: Faunae of cerianthids of the Atlantic Ocean and composition of the genus *Cerianthus*.

MSc (zoology) Moscow State University, Moscow, 1994. Diploma work: New cerianthids from the 14 cruises of RV *Professor Shtockman* and discussion of the genus *Cerianthus*.

Professional Employment:

Collection manager, P.P.Shirshov Institute of Oceanology, Russian Academy of Sciences, June 1997 - present

Publications:

1. Molodtsova, T.N., Malakhov V.V., On the biology of *Cerianthus lloydii* Gosse (Anthozoa, Cnidaria) from Kraternaja Bay (Kuril Islands). Cnidarians: Modern and perspective investigations. Proceedings of the Zoological Institute, Russian Academy of Science, vol. 261. pp. 90-94 (in Russian)
2. Molodtsova, T.N., Malakhov V.V., *Cerianthus lloydii* (Anthozoa, Ceriantharia) from the volcanic ecosystem of Kraternaya Bay: Morphology and anatomy of adult polyps, geographical distribution. Zoologicheskii Zhurnal, 1995, Vol.74.10. pp. 5-17 (in Russian) [translation into English: Hydrobiological Journal, Volume 33, Number 5 (1997)]
3. Molodtsova, T.N., Malakhov V.V., *Cerianthus lloydii* (Anthozoa, Ceriantharia) from the volcanic ecosystem of Kraternaya Bay: Larval development. Zoologicheskii Zhurnal, 1995, Vol.74. 11. pp. 4-11 (in Russian)[translation into English: Hydrobiological Journal, Volume 33, Number 6&7 (1997)]

BIOGRAPHICAL SKETCH of JOHN S. RYLAND

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Positions held:

University of Wales Swansea

Research Professor in Marine Biology, 1994 -

Professor of Marine Biology, School of Biological Sciences, 1988-1994

Professor and Head of Department of Zoology, 1981-1987

Professor 1977

Lecturer in Marine Biology, Dept. of Zoology, 1965-1976

Elsewhere:

Senior Scientist, Ministry of Agriculture and Fisheries, Fisheries Laboratory, Lowestoft, England, 1960-1965

Post-Doctoral Fellow, University of Bergen, Norway, and Stazione Zoologica, Naples, Italy, 1959-1960

Commissioned, Royal Air Force, 1954-1956

Education:

Ph.D. (marine biology) 1959 University of Wales Bangor

B.A. (zoology) 1954 (1st class honours) University of Cambridge, England

Professional Development:

President, European Marine Biology Symposia, 1996-1999

Fulbright Senior Scholar, Smithsonian Institution at Link Port, Harbor Branch Oceanographic Institution, Fort Pierce, Florida, 1993

Senior Queen's Fellow in Marine Science, Australian Institute of Marine Science, Townsville, and James Cook University of North Queensland, 1985

Professor of Biology, University of the South Pacific, Fiji [Secondment] 1978-1981

President, International Bryozoology Association, 1974-1977

Chairman, Marine Biology Board of Studies, School of Biological Sciences, University of Wales Swansea (1976-1978, 1988-1993)

Nuffield Fellow in Tropical Marine Biology, James Cook University of North Queensland, 1971-1972

Sometime Council member: Society for Experimental Biology, Linnean Society of London, Systematics Association, International Society for Reef Studies

Grants related to proposal:

Fijian Zoanthidea (Natural Environment Research Council, 1981-1982)

Reproduction of British zoanths (Natural Environment Research Council, 1991-1996)

Zoanthid reproduction and Semper's larvae (Smithsonian Institution, 1993)

Zoanthid reproduction and Semper's larvae (Leverhulme Trust, 1994)

Nematocysts in species-level anthozoan taxonomy: a question of size (Natural Environment Research Council, 1996-1998)

Anthozoan nematocysts: some questions of size (Nuffield Foundation bursary for summer student, 1996)

The breeding biology of a tropical anthozoan (Nuffield Foundation bursary for summer student, 1997)

Overseas Travel Grants (Royal Society: South Africa 1997 and Bermuda 1999) and Grant-in-Aid (The spawning, development and larva of *Parazoanthus parasiticus*, Bermuda Biological Station, 1999)

Five publications most closely related to proposed research:

Muirhead, A. & Ryland, J.S. 1985. A review of the genus *Isaurus* Gray, 1828 (Zoanthidea), including new records from Fiji. J. nat. Hist. 19: 323-335.

Ryland, J.S. & Muirhead, A.M. 1993. Order Zoanthidea, pp. 52-58 P. Mather & I. Bennett (eds): A coral reef handbook, ed. 3. Surrey Beatty, Sydney.

Ryland, J.S. 1997. Reproduction in Zoanthidea (Anthozoa: Hexacorallia). Invert. Reprod. Devel., 31: 177-188.

Burnett, W.J., Benzie, J.A.H., Beardmore, J.A., & Ryland, J.S. 1997. Great Barrier Reef and Torres Straits zoanths (Cnidaria, Hexacorallia): systematics, evolution and a key to species. Coral Reefs 16: 55-68.

Ryland, J.S. 1997. Budding in *Acrozoanthus* Saville-Kent, 1893 [Anthozoa: Zoanthidea], Proceedings of the 6th International Conference on Coelenterate Biology (eds J.C. den Hartog et al.), Nationaal Natuurhistorisch Museum, Leiden, pp 423-428.

Five other publications:

Cornelius, P.F.S., Manuel, R.L. & Ryland, J.S. 1990. Cnidaria, pp. 101-180 in Hayward, P.J. & Ryland, J.S. (eds): Marine fauna of the British Isles and north-west Europe, 2 vols. Oxford, Oxford University Press. 996 pp.

Babcock, R.C. & Ryland, J.S. 1990. Larval development of a tropical zoanthid (*Protopalythoa* sp.). Invert. Reprod. Devel. 33: 229-236.

Ryland, J.S. & Babcock, R.C. 1991. Annual cycle of gametogenesis and spawning in a tropical zoanthid, *Protopalythoa* sp. Hydrobiologia 216/217: 117-123.

Burnett, W.J., Benzie, J.A.H., Beardmore, J.A., & Ryland, J.S. 1994. High genetic variability and patchiness in a common Great Barrier Reef zoanthid (*Palythoa caesia*). Marine Biology 121: 153-160.

Shaw, P., Ryland, J.S. & Beardmore, J.A. 1994. Population genetic parameters within a sea anemone family (Sargartiidae) encompassing clonal, semiclinal and aclonal modes of reproduction, pp 351-358 in A.R. Beaumont (ed.) Genetics and evolution of aquatic organisms, London, Chapman & Hall, 539 pp.

Collaborators during last 48 months (zoanthids)

Ray Williams (Tring, UK) - Zoanthid nomenclature

Doerte Westphalen (Bermuda Biological Station) - Breeding of *Parazoanthus*

John Lancaster (Swansea) - Zoanthid nematocysts

Dmitry Zhadan (Department of Invertebrates, Moscow State University) - Carcinoecium-forming *Epizoanthus*

Rudolf S. Scheltema (Woods Hole Oceanographic Institution) - Semper's Larvae

Graduate student (current)

Samantha de Putron (Swansea and Bermuda Biological Station)

CURRICULUM VITAE of J. E. N. Veron

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Email: jveron@aims.gov.au telephone/fax 61 (7) 47534274

EDUCATION

1966 Bachelor of Science (Hons), University of New England (Australia)
1968 Master of Science, University of New England (Australia)
1972 Doctor of Philosophy, University of New England (Australia)
1982 Doctor of Science, University of New England (Australia)

CAREER

1967-68 Research Assistant, University of New England
1968-72 Teaching Fellow, University of New England
1972-75 Research Fellow, James Cook University of North Queensland
1975-95 advance from Research Scientist to Senior Principal Research Scientist, Australian Institute of Marine Science
Present Chief Scientist, Australian Institute of Marine Science

EXPERIENCE (selected)

- * Leader of Reef Studies and Reef Ecology research groups.
- * Referee/assessor for the ARC, the MST Grants Scheme, the Queen's Fellowship Committee, the Winston Churchill Memorial Trust and overseas granting agencies in the U.S.A., U.K., France, Saudi Arabia and S.E. Asian countries.
- * Organiser of 6 conferences/workshops.
- * Teaching zoology, genetics, physiology, psychology, marine biology in Australia, U.K., U.S.A., SE Asian countries.
- * Field research in all Australian coral reef regions, Marshall Islands, Hong Kong, Thailand (many regions), Papua New Guinea (many regions), Israel (Eilat), Philippines (many regions), Vanuatu, Japan (all reef regions), Hawaii, Caribbean (Jamaica, Barbados, Belize, Bahamas), Miami, Clipperton Atoll, Vietnam, Egypt, Tanzania, Brazil, Madagascar, Taiwan, Indonesia

INVITED PARTICIPATIONS (selected)

1976 Coral Taxonomy Workshop, Marshall Islands
1984 Coral Taxonomy Workshop, Phuket, Thailand
1984 Coral Workshop, Ishigaki Island, Japan
1986 Coral Taxonomy Workshop, Philippines
1986 SCOR Workshop, Hobart
1987 Coral Reef Workshop, Okinawa, Japan
1990 International Ecology Congress, Japan
1993 International Symposium on Biodiversity, USA
1993 Forum and Colloquium on Coral Reefs, USA
1996 Western Marine Conference, San Francisco
1997 Coral Taxonomy Workshop, Tanzania
1997 Coral Biodiversity Workshop, Singapore
1997 Coral Reef Conference, Brazil
1998 Pacific Science Intercongress, Taiwan, China

SOCIETY MEMBERSHIPS:

Former President and Vice President and Council Member of the Australian Coral Reef Society; Australian Marine Sciences Association; Pacific Sciences Association; PACON; International Society for Reef Studies; Society for Fossil Cnidaria; Fellow, Australian Institute of Biology.

AWARDS

- * Whitley Medal, 1987
- * Silver Jubilee Pin, Australian Marine Sciences Association, 1996

FIVE PUBLICATIONS MOST CLOSELY RELATED TO THE PROPOSED RESEARCH:

- Veron, J.E.N. (1987) Corals of Australia and the Indo-Pacific. Hawaii University Press. 642 pp.
- Veron, J.E.N. (1992) Hermatypic corals of Japan. AIMS Monograph Series 9. 234 pp.
- Veron, J.E.N. (1993) A biogeographic database of hermatypic corals: species of the central Indo-Pacific, genera of the world. AIMS Monograph Series 10. 433 pp.
- Veron, J.E.N. and L. Marsh (1988) Records and annotated check list of the hermatypic corals of Western Australia. Records Western Australian Museum Supplement 29.
- Veron, J.E.N. (in press) Corals of the World. 3 volumes. Australian Institute of Marine Science. 1,402 pp.

FIVE OTHER PUBLICATIONS:

- Veron, J.E.N. (1995) Corals in space and time: the biogeography and evolution of the Scleractinia. University of New South Wales Press. 321 pp.
- Veron, J.E.N. and Hodgson, G. (1989) Annotated checklist of the hermatypic corals of the Philippines. Pacific Science 43: 234-287.
- Veron, J.E.N. and M. Pichon (1976) Scleractinia of eastern Australia. Part I. Families Thamnasteriidae, Astrocoeniidae, Pocilloporidae. AIMS Monograph Series 1, 86 pp.
- Veron, J.E.N. and M. Pichon (1982) Scleractinia of eastern Australia. Part IV. Family Poritidae. AIMS Monograph Series V, 210 pp.
- Veron, J.E.N. and C.C. Wallace (1984) Scleractinia eastern Australia. Part V. Family Acropo

V. Budgetary information

1. Justification

1. Equipment: The project will require extensive manipulation and transmission of large data files and complex graphics images; fast, high-capacity computers are essential. We will acquire one PC workstation and one Macintosh G4 graphics station, primarily for use by subtasks 2a and 2b. Internet provision of interactive map sites places extremely high demands on the server; we will add a high-end Windows NT server to the KGS Internet computer facility to be dedicated to interactive map and database support. Note that existing computers in the investigators' institutions will be adequate for general data-entry, word-processing and administrative work.

2. Travel: Although much of the project communication will be accomplished electronically, travel is essential for making the three-way link between the anemone database, the hermatypic coral database, and the computer contractors who will combine them (one international trip for 2, year 1). A training workshop will be held early in year 1 in Kansas; Cairns' travel is budgeted (the other participants have travel budgets as part of their subcontract or consulting contract). Also in year 1, two domestic trips are planned to firm up data exchange and software compatibility arrangements with the unfunded partners and collaborators (e.g. NOAA, NCAR). Travel relating to LOICZ and NCRI participation will be funded by those contracts. In year 2, three trips are budgeted to provide meeting and/or workshop exposure to the products in the information dissemination stage.

3. Contracts and consultancies: The Task 4 (Cairns, Smithsonian) contract provides for the cost of the extensive literature search, copy and mailing costs required to get the primary literature into the database. Under Task 5, Ryland (U. Wales) will receive funds to support a student for literature search, review, and data entry, plus travel to the project meetings and incidental (copy, communication) costs. In Task 6 there are no direct outlays to Veron, but related computer software support appears as part of the B&P contract. Molodtsova will complete Task 7 under a consultancy agreement, making two trips to Kansas -- the first for training and entry of the data on adult cerianthids, and a subsequent one for proof-reading, verification, and entry of information on larval forms. The Bits&Parity contract provides software and data support that cuts across the various tasks; it will assist in acquiring, formatting, and preparing for internet distribution many of the environmental databases, it will do the necessary coding and verification to import datasets from other formats and software packages into the database, and it will assist with design of interfaces and graphical front ends for the linked taxonomic-geographic tools to be developed.

The breakdown of direct costs (requested NOPP funding only) by task is given in the following table:

Cost Allocation, Project tasks (see note 1)														
Task	Personnel (see note 2)						Exp.	Equip	Subcontracts			Cons	Travel	Total
	RB	GM	JB	AA	GA	SH			B&P	JR	SC			
1	7491	25192	17402		8701	3548	3600	5333	7000				4260	82528
(1a)	1873					1774			2000					5647
(1b)	5618	25192	17402		8701	1774		5333	5000				4260	73281
2	11237	16795	26104	21753	34805	7095	8400	10667	9000				6650	152505
(2a)	1873	4199	8701	21753	13052	5321		5333	5000				3750	68982
(2b)	9364	12596	17402		21753	1774		5333	4000				2900	75123
3				21753		7095								28848
4						12417					5000		2500	19917
5						1774				28915				30689
6						1774			4000				3750	9524
7						1774						21110		22885
Total	18728	41987	43506	43506	43506	35476	12000	16000	20000	28915	5000	21110	17160	346895
note 1	Amounts are calculated as percentages of the total direct cost budget items, rounded to nearest \$													
note 2	Named participants are identified by initials; GA = graduate assistant, SH = student hourly employees.													
note 3	Exp. = sum of supplies & materials, communications, publications													

2. Budget

VI. Supporting information

A. Other current and pending research projects being undertaken by the principal investigator(s):

PI:

National Science Foundation Grant DEB-9521819 (PEET program), "Inventory, systematics, and phylogeny of sea anemones: training of modern systematists and electronic dissemination of data," Sept 1995 - Sept 2000

Research Experience for Undergraduates supplement to DEB-9521819, May 1999 – May 2000

National Science Foundation Grant DEB-9978106 (PEET program), Sept 2000 - Sept 2005: "Sea anemone systematics: consolidation and synthesis of information" (approved but not yet awarded)

Co-PI:

National Science Foundation Grant DEB 9711621, "Biodiversity consequences of global climate change in Mexico." PI: A. T. Peterson, co-inv. K. Price/S. Egbert; R. Buddemeier; V. Sanchez-Cordero/J. Soberon-Maniero. Oct 1997-Sep 2000

National Coral Reef Institute (Nova Southeastern University): "Coral reef vulnerability: an electronic reef environmental database," Aug 1999- Sep 2000

New Energy and Industrial Technology Organization (NEDO -- Japan): "Feasibility study of an ecoengineering-based method to increase atmospheric CO₂ fixation into a marine ecosystem" Typology task (S. Kraines and Masahiko Isoke, Univ. of Tokyo, PIs), Aug 1999- Mar 2000

UNEP-GEF (to LOICZ): "Global synthesis of coastal zone biogeochemical function" (Typology task), Jun 1999- Dec 2002

Kansas Water Office: "High Plains Aquifer Evaluation" Study D. O. Whittemore (PI), R. W. Buddemeier, C. McElwee, M. A. Townsend, M. A. Sophocleous, P. A. Macfarlane, D. P. Young, and J. A. Schloss, Jul 1999- Jun 2000

Kansas Department of Health and Environment: "TMDL Evaluation Study," D. O. Whittemore (PI), R. W. Buddemeier, P. A. Macfarlane, and D. P. Young, Feb 1999-Jun 2000

B. Institution participation and support

See various sections above. Explicit financial matches from the University of Kansas are 10% of Fautin's time and 5% of a computer professional's time. Portions of the project will receive contributions from other grants and contracts of the PI and co-PI.

C. Other agencies receiving proposal and/or currently supporting the effort

No other institutions are receiving this proposal.

D. Letters of individual participation

1. Cairns
2. Molodtsova
3. Ryland
4. Veron

E. Letters of endorsement/institutional participation

1. LOICZ
2. ICLARM
3. NCRI
4. NOAA
5. Bits & Parity
6. Opresko