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***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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<http://www.kgs.ukans.edu/Hexacoral/>

Long-Term Goals

We are creating an easy-to-understand data source for 1) taxonomic and distributional information about hexacorallian animals (corals, sea anemones, and their kin) and 2) relevant environmental parameters. User-friendly tools link biogeographic information across spatial scales, thereby greatly augmenting the minimal biogeographic data available for most benthic marine invertebrates. Such interactions between the biological and environmental data allow them to be visualized, analyzed, and extracted, as desired. In particular, the tools permit formulation and testing of biogeographical and biodiversity models, and support forecasting and hindcasting of distribution changes due to environmental alteration.

Objectives

To accomplish these goals, we had planned to:

1) Create a taxonomic database to all hexacoral species except Antipatharia (black corals); these belong to orders Corallimorpharia and Actiniaria (sea anemones; already compiled by Fautin), Ceriantharia (tube anemones), Scleractinia ("stony" or "true" corals), and Zoanthidea (zoanthids). Specimen-based, it was planned to contain three-dimensional distribution data

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(including geospatial precision of each record) and bibliographic reference to the description of each species.

2) Develop an application to permit retrieval of data by all synonyms of a species, flagging taxonomic and nomenclatural problems.

3) Allow interaction of this database with 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](http://www.nioz.nl/loicz)).

4) Develop and adapt tools to allow interactive analyses of the biological and environmental data, including by visualization on map displays.

### Approach and Work Plan

The biological data augmented those in a database in Oracle begun by Fautin on two grants from NSF in the program Partnerships to Enhance Expertise in Taxonomy (PEET). Acquired from the published literature, they were keyboarded and then proof-read by students. The environmental data for the world ocean and coastal zone, which were acquired in cooperation with the partner project LOICZ (Land-Ocean Interactions in the Coastal Zone; IGBP), were gridded into 0.5° cells; distribution of cells is shown on maps at [water.kgs.ukans.edu:8888/public/Typpages/typcells\\_1.htm](http://water.kgs.ukans.edu:8888/public/Typpages/typcells_1.htm). Data entry for the

biological data and queries of the database are in ColdFusion. “Hexacorral” is the name by which we refer to the website that serves both these databases and links them.

### Personnel

#### Individuals

Adorian Ardelean, University of Kansas, USA - developing the synonymy tool

Stephen D. Cairns, Smithsonian Institution, USA - providing data for Scleractinia

Laura David, Bits & Parity, Manila, Philippines - entering data for Scleractinia

Tina Molodtsova, Shirshov Institute of Oceanology, Russia - providing data for Ceriantharia

John Ryland, University of Wales, UK - providing data for Zoanthidea

J. E. N. Veron, Australian Institute of Marine Science, Australia - providing data for Scleractinia

#### Institutions

LOICZ (IGBP), Netherlands – support for development of clustering tool, LOICZView

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ICLARM, Malaysia; NCRI (Nova University), Florida, USA; NOAA, USA – liaison to providers of and users of data on corals and coral reefs

The project is currently on a 1-year no-cost extension that will expire in September 2003. A new version of the database released in January 2003 incorporates additional environmental data including modeled SSTs back to the 1870s, several thousand more georeferenced specimen records (primarily for corals), and a tool allowing the user to select multiple species and environmental parameters for analysis. A further update to be released during summer of 2003 will incorporate more biological and environmental data, and will correct any problems users have found with the tool.

### Work Completed

This report emphasizes accomplishments during 2002; activities during 2000 and 2001 were reported previously (those reports are available at [www.kgs.ukans.edu/Hexacoral/Products/products.htm](http://www.kgs.ukans.edu/Hexacoral/Products/products.htm)). Early in the project, names of all cerianthids and zoanthids were entered, and many scleractinian names were as well. The number of scleractinian coral species is about the same as that of actinarians, a complete inventory of which exists in the database, but the volume of literature and the number of coral names greatly exceeds that for actinarians; entry of scleractinian names continues, and a proposal was recently submitted to NSF for a project that includes completing the inventory of these animals.

Hexacoral now contains more than 100 environmental variables drawn from publicly available global coverages, and adapted to format requirements. Expansions and improvements include:

- Addition of new and better ocean wind, tide range and frequency, ETOP2 bathymetry datasets, and updating of previously acquired climatologies and water balance datasets.
- Addition of long-term sea-surface temperature time series.
- Addition of inland grid cells to make the geographic coverage truly global.
- Developing a system of dynamically selectable database subsets to simplify variable selections for various types of users and applications.
- Expanding the variable manipulation options by adding additional transformations, filters, and a calculator function to the operations that can be performed on selected variables.

Search, selection, and visualization tools developed and implemented include:

- Multiple geographic location entry options (the ‘location cart’) with subsequent links to the environmental and biological database search and selection.

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- A selection tool for multiple taxa (the ‘taxon cart’), with transfer of georeferenced locations to the environmental database and extraction of associated variables for each taxon and combination.
- Development of dynamic mapping options to display areas designated by user choice, biodatabase specimen records, and/or environmental characteristics.

Development of interoperability with:

- The OBIS portal ([www.iobis.org](http://www.iobis.org))
- FishBase ([www.fishbase.org/search.html](http://www.fishbase.org/search.html)) and CephBase ([www.cephbase.utmb.edu/](http://www.cephbase.utmb.edu/)) projects, which are using the environmental database and mapper on a bilateral interoperability basis.
- NMITA (fossil coral database; [porites.geology.uiowa.edu/index.htm](http://porites.geology.uiowa.edu/index.htm)), linking taxonomic and other information on relevant coral species held in either or both of the two databases.


Many thousand georeferenced records for specimen occurrences were entered and proofread during 2002. Among them were those from the monograph by Wallace on *Acropora*, the largest genus of reef-forming corals. Entry of these records provided an opportunity to develop a protocol for batch importation of specimen data, as well as making data from Wallace’s book available electronically and enhancing the database.

In addition to what had been planned for Hexacorallia, an REU supplement to Fautin’s PEET grant allowed Ryan Schulze to enter virtually all names of members of Antipatharia, the black corals, which was the only hexacorallian order that had not been included in the database. He built the classification of black corals, incorporated more than 400 scanned images from original descriptions, and linked synonymous names for about 100 valid species, using the application Syngraph, developed by NOPP-supported graduate student Ardelean ([web.nhm.ukans.edu/inverts/syngraph/index.htm](http://web.nhm.ukans.edu/inverts/syngraph/index.htm)). Another REU supplement allowed Dan Atwater to create a module for common names. This permits users to query the database using names that appear in the hobby literature (such as aquarium and dive books).

Ganesh Shankaran, the PEET-supported student acting as Systems Administrator for the project, is completing standardizing the gazetteer so locality data can be entered and accessed more easily. In January 2003, Fautin was awarded a grant through the KU Digital Libraries Initiative to put into electronic form information about stations of the 1872-1876 expedition of the British ship *Challenger*. In addition to being added to the gazetteer and being tied to specimens in the database, they will be available for use by others – including educators – dealing with information from the *Challenger*. This prototype will be the model for treatment of other biologically important expeditions such as the German Deep-Sea Expedition, the Norwegian North Atlantic Expedition, and Scott’s Antarctic expeditions; Fautin is applying for an REU supplement for a student to develop more such modules.

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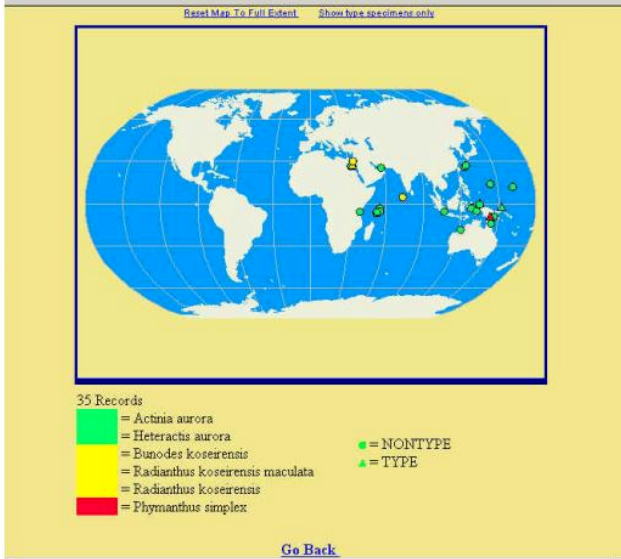
Funds secured from other sources that it was possible to obtain because of the NOPP funding, and that contributed to the NOPP effort, include, to Ardelean, a student award from the KU Natural History Museum to help with travel expenses for the Ocean Science Meeting of American Geophysical Union, Honolulu, in February, 2002, and a student award through KU NSF Epscor to travel to the Evolution Meeting at the University of Illinois, Urbana-Champaign in July 2002. Fautin received an REU supplement award to support two students, one to add the antipatharians to Hexacoral coverage and one to add common names to it.



Occurrence records displayed on a map use symbols of a **different color for each synonymous name**. This function can be used for investigating whether a synonymy is justified.

**“Hexacoral” as a research tool**

Result of searching database for the sea anemone currently known as *Heteractis aurora*, then selecting the option “Distribution.” Occurrence points are color-coded according to the name used in publication for the species.



35 Records

- = Actinia aurora
- = Heteractis aurora
- = Eunodes koseirensis
- = Radianthus koseirensis maculata
- = Radianthus koseirensis
- = Phymanthus simplex
- = NONTYPE
- ▲ = TYPE

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For taxa with georeferenced records, a query of the companion global 30' environmental database produces summaries of general environmental conditions for individual entries or a summary for the taxon



Companion environmental records for *Heteractis aurora* (which was searched for under the name *Actinia aurora*). These results represent mean, maximum, and minimum values for the four default environmental parameters -- SST, salinity, ocean color, and depth. The user can select other parameters.

### Results

Since the goal of the project is development of a useful information system, the accomplishments listed above are in fact 'results' in the sense of the project objectives.

Additional scientific results have been obtained through application and testing of the capabilities, and are indicated in the project publications. In particular, the databases and tools have been applied to a number of evaluations and analyses of coastal zone (Buddemeier et al. 2002a, b) and coral reef habitats (Buddemeier and Fautin 2002a, b, Scavia et al. 2002, McLaughlin et al. in press, Guinotte et al. submitted). Initial research on the project shown in the poster by Baker et al. (2002) was done by Baker, a student in the REU site program at the University of Kansas during summer 2001.

### Impact/Applications

#### Science Education and Communication

The Hexacoral site is currently unique in terms of the combination of taxonomic and environmental detail and visualization and applications tools it can combine for user download or analysis. This makes possible the formulation and answering of questions and the exchange of tailored information packages that would be tedious or impossible using separate electronic databases or non-electronic information resources. In turn, this opens the door to forms of education, public information, and research that are only starting to take shape, but that will transform the scales at which subjects are taught and understood.

As a member of the OBIS federation, Hexacoral can interact with nearly a dozen other databases so broad, cross-taxon biogeographic patterns can be assessed. The tools for effective interactivity, which are just being developed, have enormous potential for the future.

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The functionality of searching by common name, developed by an REU student, will make Hexacoral more accessible to non-scientists.

Buddemeier, Fautin, and Karen Stocks (Scripps Institution of Oceanography) organized a special session concerned with biogeoinformatics at the Ocean Science meeting in Honolulu during February 2002.

Students supported by this grant have been receiving valuable professional training. Among them are Ardelean, Hunsinger, McLaughlin, and Sandhei, all of whom have made presentations at professional meetings. Other students, including those on REU grants, have been associated with the grant. Students and a post-doctoral fellow supported on Fautin's PEET grant have also contributed to the Hexacoral effort.

### Transitions

#### Science Education and Communication

The structure of the biological portion of Hexacoral is being used for a database on stomatopods being developed by Dr. Marjorie Reaka-Kudla at the University of Maryland; this database will ultimately be served by OBIS. The structure will be used by Dr. Eric Thuesen (Evergreen State College, Washington) and collaborators if they are awarded a grant to inventory gelatinous zooplankton through the NSF competition Planetary Biodiversity Inventory; it, too, will be served by OBIS.

### Consideration for Excellence in Partnering Award

**Ocean Sector Diversity:** The Hexacoral project deals with all sectors of the world ocean.

**Partner Involvement:** Partners include academic, government, and business concerns in Asia, Europe, and Australia, in addition to the US.

**Matching Contributions:** In addition to expertise, which was provided by most partners, some provided funds or in-kind support (e.g. LOICZ and NCRI).

**Partner Long-Term Commitment:** Some of the partner individuals involved in publications still being written, meetings currently being planned, and grant proposals recently submitted and still being planned.

**Success in Project Objectives:** The Hexacoral project was an extremely collaborative one, meeting and far exceeding its goals.

### Related Projects

As mentioned above, among the accomplishments of Hexacoral in 2002 was achieving interoperability with other databases. Bilateral relationships currently exist with three databases. FishBase ([www.fishbase.org/search.html](http://www.fishbase.org/search.html)) and CephBase ([www.cephbase.utmb.edu/](http://www.cephbase.utmb.edu/)) are using the Hexacoral environmental database and mapper. NMITA ([porites.geology.uiowa.edu/index.htm](http://porites.geology.uiowa.edu/index.htm)) also uses the environmental data and provides taxonomic and other information on relevant fossil corals. Hexacoral data are served through the OBIS portal ([www.iobis.org](http://www.iobis.org)), along with the data from nearly a dozen other databases (including

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FishBase and CephBase); the environmental data and mapping tool of Hexacoral serve all the databases, individually or in combined searches.

### Publications

(Items in italics represent either applications or development of the Hexacoral/LOICZ database and tools; other items address the subject as well as the methods of the hexacoral project.)

Buddemeier, R.W., C. J. Crossland, B. Maxwell, S. V. Smith, D. Swaney, J. D. Bartley, G. Misgna, C. Smith, V. C. Dupra, and J. I. Marshall Crossland (eds.). 2002a. LOICZ/UNEP regional synthesis workshops: Australasia–Asia, the Americas, Africa-Europe. Summary report and compendium. LOICZ Reports & Studies No. 22, LOICZ, Texel, The Netherlands, i + 76 pages.

Buddemeier, R. W. and D. G. Fautin. 2002a. Editorial: Social behavior in a research society. *Coral Reefs* 21(1):9-11.

Buddemeier, R. W. and D. G. Fautin. 2002b. Overview -- Large-scale dynamics: the state of the science, the state of the reefs, and the research issues. *Coral Reefs* 21(1):1-8.

Buddemeier, R.W., S. V. Smith, D. P. Swaney, and C. J. Crossland. 2002b. The role of the coastal ocean in the disturbed and undisturbed nutrient and carbon cycles. LOICZ Reports & Studies No. 24, LOICZ IPO, Texel, The Netherlands, ii + 83 pages.

Fautin, D. G. 2002. Reproduction of Cnidaria. *Canadian Journal of Zoology* 80(10):1735-1754.

Fautin, D. G., T. R. White, and K. E. Pearson. 2002. Two new species of deep-water Corallimorpharia (Cnidaria: Anthozoa) from the northeast Pacific, *Corallimorphus denhartogi* and *C. pilatus*. *Pacific Science* 56(2):113-124.

Maxwell, B. A, and R. W. Buddemeier. 2002. Coastal typology development with heterogeneous data sets. *Regional Environmental Change* 3:77-87.

*Peterson, A. T., V. Sanchez-Cordero, J. Soberon, R. W. Buddemeier, J. Bartley, and D. R. B. Stockwell. 2002. Future projections for Mexican faunas under global climate change scenarios. Nature 416: 626- 629.*

Randall, J. E. and D. G. Fautin. 2002. Fishes other than anemonefishes that associate with sea anemones. *Coral Reefs* 21(2):188-192.

Scavia, D., J. C. Field, D. F. Boesch, R. W. Buddemeier, V. Burkett, D. R. Cayan, M. Fogarty, M. A. Harwell, R. W. Howarth, C. Mason, D. J. Reed, T. C. Royer, A. H. Sallenger, and J. G. Titus. 2002. Climate change impacts on U.S. coastal and marine ecosystems. *Estuaries* 25:149-164

Smith, S. V., W. H. Renwick, J. D. Bartley, and R. W. Buddemeier. 2002. Distribution and significance of small, artificial water bodies across the United States landscape. *The Science of the Total Environment* 299: 21-36.



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### In Press or submitted:

Daly, M., A. Ardelean, H.-R. Cha, A. C. Campbell, and D. G. Fautin. In press. A new species, *Adamsia* \*\*\* (Cnidaria: Anthozoa: Actiniaria), from the Gulf of Mexico and a discussion of the taxonomy of carcinoecium-forming sea anemones. *Bulletin of Marine Science*

Daly, M., D. G. Fautin, and V. C. Cappola. submitted. Systematics of Zoantharia. *Zoological Journal of the Linnean Society*

Guinotte, J. M., R. W. Buddemeier, and J. A. Kleypas. submitted. Future coral reef habitat marginality: temporal and spatial effects of climate change in the Pacific basin. *Coral Reefs*.

McLaughlin, C. J., C. S. Smith, R. W. Buddemeier, J. D. Bartley, and B. A. Maxwell. in press. Rivers, runoff, and reefs. *Journal of Global and Planetary Change Special Issue: the supply and flux of sediment along the hydrological pathways: anthropogenic influences at the global scale*.

*Smith, S. V., D. P. Swaney, L. Talaue-McManus, J. D. Bartley, P. T. Sandhei, C. J. McLaughlin, V. C. Dupra, C. J. Crossland, R. W. Buddemeier, B. A. Maxwell, and F. Wulff. in press. Humans, hydrology, and the distribution of inorganic nutrient loading to the ocean. BioScience.*

### Presentations at Scientific Meetings

Ardelean, A. 2002. Environmental GIS modeling of distribution patterns in *Actinodendron plumosum*, a sea anemone with a large geographic range [abstract]. Eos, Transactions of the AGU, Ocean Sciences Meeting Supplement 83:OS42C-141. [Outstanding Student Poster Award]

Ardelean, A. 2002. Predicted geographic distributions aid taxonomic decisions within sea anemone genus *Actinodendron* (Anthozoa: Actiniaria). Evolution Meeting. University of Illinois at Urbana-Champaign.

Baker, J., P. Sandhei, and D. G. Fautin, 2002. Ocean-scale biogeography: predicted distributions of anemonefish sea anemones [abstract]. Eos, Transactions of the AGU, Ocean Sciences Meeting Supplement 83:OS42C-140.

Buddemeier, R. W., B. A. Maxwell, and J. D. Bartley. 2002a. The concept or the number [abstract]. Eos, Transactions of the AGU, Ocean Sciences Meeting Supplement 83:OS41M-10.

Buddemeier, R. W., C. J. McLaughlin, and P. Sandhei. 2002b. Reefs as habitats or habitats for reefs: global-scale coral reef biogeography [abstract]. Eos, Transactions of the AGU, Ocean Sciences Meeting Supplement 83:OS11S-05.

Fautin, D. G. 2002. Non-electronic sources of biogeographical data [abstract]. Eos, Transactions of the AGU, Ocean Sciences Meeting Supplement 83:OS32J-01.

Hunsinger, K. L. 2002. Evaluating standards for digital representation of locality information [abstract]. Eos, Transactions of the AGU, Ocean Sciences Meeting Supplement 83:OS42C-139.

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McLaughlin, C. J. and C. S. Smith. 2002. Land forcing and coral reefs: terrestrial runoff as a factor in coral reef distribution [abstract]. Eos, Transactions of the AGU, Ocean Sciences Meeting Supplement 83:OS32J-06.

Misgna G., J. D. Bartley, and R. W. Buddemeier, 2002. Data data everywhere – and not a way to choose [abstract]. Eos, Transactions of the AGU, Ocean Sciences Meeting Supplement 83:OS42C-138.

### Other presentations

Buddemeier, R. W. Invited presentation on: “Climate Change and Coral Reefs” in the Capitol Hill Oceans Week 2002 Symposium [<http://www.nmsfocean.org/chow/>], Coral Reefs at Risk: Challenges and Solutions. June 6, 2002, Washington, D. C. (handouts and slide shows at [www.kgs.ukans.edu/Hexacoral/Products/products.htm](http://www.kgs.ukans.edu/Hexacoral/Products/products.htm))

Buddemeier, R. W. Invited testimony presented to the June 27, 2002 hearing on: Implementation of the Coral Reef Conservation Act of 2000 and the impact of climate change on coral reefs. Held by the Subcommittee on Fisheries Conservation, Wildlife and Oceans (Hon. Wayne Gilchrist, Chair), Committee on Resources, U.S. House of Representatives, Washington, D. C. (handouts and slide shows at [www.kgs.ukans.edu/Hexacoral/Products/products.htm](http://www.kgs.ukans.edu/Hexacoral/Products/products.htm))

Buddemeier, R. W. Invited presentation (“Changing Climate and Coral Reefs”) to the Meeting of the US Coral Reef Task Force [<http://coralreef.gov/dec2002.cfm>], San Juan Puerto Rico, Oct. 2-3, 2002. (handouts and slide shows at [www.kgs.ukans.edu/Hexacoral/Products/products.htm](http://www.kgs.ukans.edu/Hexacoral/Products/products.htm))

Fautin, D. G. Biogeoinformatics of hexacorals. Invited presentation at conference The known, the unknown, and the unknowable, Scripps Institution of Oceanography, 6-9 December 2002 (slide show at [web.nhm.ukans.edu/inverts/abstracts/index.htm](http://web.nhm.ukans.edu/inverts/abstracts/index.htm))

Fautin, D. G. and R. W. Buddemeier. Invited presentation at NOAA Central Library, 21 November 2002. Corals and sea anemones on line: a functioning biodiversity database (slide show at [web.nhm.ukans.edu/inverts/abstracts/index.htm](http://web.nhm.ukans.edu/inverts/abstracts/index.htm))

Fautin, D. G. and R. W. Buddemeier. Invited presentation at Colour of Ocean Data conference 27 November 2002. Corals and sea anemones on line: a functioning biodiversity database (slide show at [web.nhm.ukans.edu/inverts/abstracts/index.htm](http://web.nhm.ukans.edu/inverts/abstracts/index.htm))

Fautin spoke about OBIS at the meeting of CORONA (Coordinating Research on the North Atlantic), Shoals Marine Laboratory, August 2002