BIOCOMPLEXITY IN THE ENVIRONMENT

The world is facing significant scientific and societal challenges, including the prospect of rapid environmental and climate change and the complicated question of long-term environmental security. The integrity of local, regional, and global ecosystems is inextricably linked to human well-being, and environmental and human health often intertwine. While exploration of complex environmental systems poses significant research challenges, it is a necessary element of local, national, and global security and critical to the development of new scientific and technological capabilities that will significantly advance our ability to anticipate environmental conditions and thus improve environmental decision-making. Thus, both scientific and practical needs for clear quantitative understanding of the world motivate continued focus on the investigation of complex environmental systems.

The *Biocomplexity in the Environment* (BE) priority area is designed to give NSF the capability to respond to the demand for new approaches to investigating complex environmental systems in which the dynamic behavior of biota is linked to the physical and chemical processes of the environment. Investigations must be highly interdisciplinary, consider non-human biota and/or humans explicitly, and examine challenging systems that have high potential for exhibiting nonlinear or highly coupled behavior. Advanced computational and mathematical modeling strategies are intrinsic to this research. The term "biocomplexity" is used to stress the requirement that research questions must address the dynamic web of interrelationships that arise when living things at all levels – from molecular structures to genes to organisms to ecosystems to urban centers – interact with their environment.

Biocomplexity in the Environment Funding

(Dollars in Millions)

	FY 2005 Actual	FY 2006 Current Plan	FY 2007 Request	Change over FY 2006 Amount	Change over FY 2006 Percent
Biological Sciences	39.86	30.43	9.43	-21.00	-69.0%
Computer and Information Science and Engineering	8.00	3.00	-	-3.00	-100.0%
Engineering	6.00	5.94	4.00	-1.94	-32.7%
Geosciences	37.22	36.85	26.11	-10.74	-29.1%
Mathematical and Physical Sciences	3.83	3.36	1.00	-2.36	-70.2%
Social, Behavioral and Economic Sciences	2.00	2.00	1.08	-0.92	-46.0%
Office of International Science and Engineering	0.71	0.25	0.13	-0.12	-48.0%
Office of Polar Programs	1.55	1.53	0.83	-0.70	-45.8%
Total, Biocomplexity in the Environment	$99.17	$83.36	$42.58	-$40.78	-48.9%

Totals may not add due to rounding.

FY 2007 is the final year of this very successful priority area. In the words of external evaluators, "BE has fostered an important new area of multidisciplinary research addressing challenging environmental questions, including the explicit role of humans." This assessment is based on the impressive response from the scientific community. In addition to research accomplishments, BE has prompted realignments of academic departments, initiation of a new journal, special conferences and sessions, and professional society meetings. In order to continue to advance a more complete and synthetic understanding of natural processes, of human behaviors and decisions in the natural world, and ways to use new technology effectively to sustain life on earth, NSF will support interdisciplinary studies of this type within the

structure of its regular programs. In FY 2007, specific programs that have demonstrated their importance and potential for innovation will be supported within the BE priority area. After FY 2007, this research portfolio will be referred to as Complexity in Environmental Systems (CES).

Long-term Goals: NSF will emphasize research and education on *Biocomplexity in the Environment*. This priority area is part of investments and accomplishments within NSF's FY 2007 environmental investment of over $850 million. The intellectual goals of the effort are to:

- Synthesize environmental knowledge across disciplines, subsystems, time and space;
- Discover new methods, models, theories, and conceptual and computational strategies for understanding complex environmental systems;
- Develop new tools and innovative applications of new and existing technologies for cross-disciplinary environmental research;
- Integrate human, societal, and ecological factors into investigations of the physical environment and environmental engineering;
- Improve science-based forecasting capabilities and enhance research on decision-making and human environmental behaviors; and
- Advance a broad range of infrastructure to support interdisciplinary environmental activities such as collaboratory networks, information systems, research platforms, international partnerships, and education activities that enhance and diversify the future environmental workforce.

Long-term Funding for Biocomplexity in the Environment
(Dollars in Millions)

FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005 Actual	FY 2006 Current Plan	FY 2007 Request
$50.00	$54.88	$58.10	$70.12	$104.11	$99.17	$83.36	$42.58

FY 2007 Areas of Emphasis: In FY 2007, NSF plans to invest $42.58 million in the interdisciplinary Biocomplexity in the Environment activities described below. Three primary areas that stress the interactions of humans and biota with both the natural and manmade environments will be supported.

- **Carbon and Water in Earth Systems** – This research aims to increase fundamental understanding of the interrelation of physical, chemical, geological, hydrologic, atmospheric, and biological processes that comprise the Earth's natural systems. In particular, it will address interdisciplinary gaps in understanding the carbon and water cycles as they pertain to life, the global environment, and climate change. Critical feedbacks, coupling, and interactions of the carbon and water cycles will be emphasized. Examples of areas that will be investigated include the oceanic mesopelagic layer, continental margins, and wetlands. Included, too, is research on the complex processes, both abiotic and biotic, that effect variability in freshwater resources.

- **Dynamics of Coupled Natural and Human Systems** – This research involves quantitative interdisciplinary analyses of relevant human and natural system processes and the complex interactions among human systems and natural systems at diverse scales. Example areas of

study include land use, the role of institutions in decision-making, and social valuation of biodiversity.

- **Materials Use: Science, Engineering and Society** – These studies are directed toward reducing adverse human impact on the total interactive system of resource use, the design and synthesis of new materials with environmentally benign impacts on complex environmental systems, as well as maximizing the efficient use of individual materials throughout their life cycles.

It is anticipated that these three areas will continue as independent programs in the future after the BE priority area ends in FY 2007. Carbon and Water in Earth Systems will be housed in the Geosciences Directorate, and Materials Use: Science, Engineering and Society will be housed in the Engineering Directorate. It is expected that Dynamics of Coupled Natural and Human Systems is expected to continue with support from several directorates.

These three areas will be complemented by multidisciplinary research and education activities that use a synthetic approach to understanding complex environmental systems. These include:

- Environmental Genomics – the integrated use of genomic and information technology methods to gain novel insights into environmental questions and problems.
- Sensor Development – development of innovative and robust sensors for use in specific challenging environmental applications.
- Education Activities – projects designed to integrate education and research on complex environmental systems and to promote workforce development, including increased participation of underrepresented minorities and the professional development of science teachers.

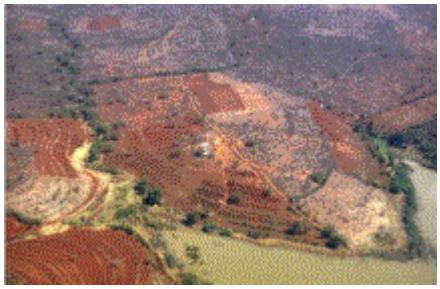
Recent Research Highlights

► **What Fisheries Management Teaches Us about Protecting Coral Reefs** With fisheries management moving more and more toward ecosystems-based approaches, instead of focusing on each fish species in isolation, a new piece of research funded under NSF's Biocomplexity in the Environment program has shown how subtle such an approach can be. It turns out that one major reason for the decline of Caribbean coral reefs is an excessive growth of seaweed. So it might seem that reefs would be healthier if they had more parrotfish and other such herbivores that could eat the seaweed. But that's not quite true, the researchers found. In "no-take" marine reserves where fishing is not allowed, the coral reefs begin to support more predator species such as grouper, and the predators, in turn, start to lower the population of parrotfishes. Yet the reef continues to thrive. The parrotfish that remain are both bigger, which helps them escape being eaten, and hungrier: they eat more than their smaller brethren, and so have a greater impact on the seaweed.

In short, this project helped demonstrate that at least one ecosystems-based management tool, no-take marine reserves, could be quite effective—for reasons that would be hard to guess in advance.

► **The Changing Landscape of East Africa** At a time when eastern Africa is undergoing extremely rapid changes in land-use patterns, from the massive migration of rural folk into cities to the steady spread of farming into savanna lands, an international team of researchers funded under NSF's Biocomplexity in the Environment program has carried out one of the first complete "close-the-loop" studies of the process. The goal of this research, conducted under the Climate-Land Interaction Project (CLIP), is to achieve a better understanding of how land-use decisions interact with climate change at regional and local scales—and how both circle back to influence future land-use decisions. For example,

one of the most striking findings so far is that rapid urbanization can actually have a major effect on rural landscapes. This is partly because the urban market for food creates an incentive for higher-intensity agriculture, and partly because most of the energy used to cook food in east African cities comes from charcoal and wood harvested from natural woodlands and savannas. The resulting shifts in land use, in turn, will likely have a large impact on the regional climate.



New farms carved out of the savanna along the Kindaruma Dam in Machakos, Kenya. *Credit: Photo courtesy of Jennifer Olson*

Such basic issues are of critical importance to governments, industry, agriculturalists, and others throughout the world. CLIP also actively engages U.S. and Eastern African students in the conduct of interdisciplinary research.