Strategic Plan

for the

U. S. Geological Survey

Fisheries: Aquatic and Endangered Resources Program

2005-2009

September 30, 2004

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EXECUTIVE SUMMARY

Looking into the Future -

- What will the aquatic biological world look like in the next 5 years?
- What critical capabilities will be needed to prepare for the changes to come?
- How will the U. S. Geological Survey, **Fisheries: Aquatic and Endangered Resources Program** respond to these needs?

The Fisheries: Aquatic and Endangered Resources (FAER) Strategic Plan has been developed through an extensive collaborative effort to predict and identify the aquatic biological information needs of our partners and customers, and to posture our science to respond to ongoing and future challenges. This plan takes an enterprise perspective, driven by crosscutting, multi-disciplinary goals and objectives. The Plan describes the current and future roles of the FAER Program and projected coordinated research with U. S. Geological Survey (USGS) disciplines, Department of the Interior (DOI) partners, and other natural resource managers.

VISION

The vision of the **USGS Fisheries: Aquatic and Endangered Resources Program** is to be a National leader in providing sound aquatic biological research and technical assistance to meet the needs of our partners within the Department of the Interior and other natural resource agencies and entities.

Strategic Direction: The strategy for the **Fisheries: Aquatic and Endangered Resources Program** over the next 5-years will:

- Increase collaboration with DOI partners and other natural resource managers in defining aquatic biological challenges and finding needed scientific solutions for aquatic organisms and freshwater, estuarine, and coastal systems.
- Re-assess and re-focus FAER research direction and funding to address our DOI partners and the Nation's aquatic biological research challenges in response to ecological and societal needs.
- Utilize the USGS' diverse scientific and technological capabilities to enhance our research expertise for resolving complex aquatic resource issues.
- Incorporate a scientific Adaptive Management framework to provide resource managers and decision makers with critical scientific and technological answers for aquatic resource management.
- Increase the visibility of USGS science capabilities and transfer of biological information to natural resource managers, decision makers and the public.

FAER PROGRAM GOALS

Fisheries: aquatic and endangered resources research activities will focus on the following primary science goals:

GOAL 1: DIVERSITY, LIFE HISTORY AND SPECIES INTERACTIONS OF AQUATIC ORGANISMS:
Provide scientific information about the ***diversity, life history and species interactions*** that affect the condition and dynamics of aquatic communities.

GOAL 2: AQUATIC ORGANISM HEALTH:
Provide scientific information about factors and processes that affect ***aquatic organism health*** in support of survival, protection, conservation and recovery.

GOAL 3: AQUATIC SPECIES AND HABITAT INTERACTIONS:
Quantify and describe functional relationships among ***aquatic species and habitats*** to provide information to conserve or restore aquatic community structure and function.

GOAL 4: AQUATIC SPECIES AT RISK:
Provide science support for natural resource managers by investigating the factors that contribute to the conservation and recovery of ***aquatic species at risk***.

GOAL 5: RESTORATION SCIENCE FOR AQUATIC SPECIES AND AQUATIC HABITATS:
Develop research and technology tools to provide the scientific basis for developing adaptive management strategies and evaluating their effectiveness for ***restoration*** efforts to sustain aquatic resources.

GOAL 6: RESEARCH SUPPORT AND TECHNICAL ASSISTANCE TO AQUATIC RESOURCE MANAGERS:
Provide ***research support and technical assistance*** to DOI bureaus, other Federal and State government agencies, Tribes, and non-governmental organizations to support natural resource management problem solving and decision making.

ORGANIZATIONAL CONTEXT AND PROGRAM ROLE

1. U.S. DEPARTMENT OF THE INTERIOR (DOI)

The DOI has responsibilities, conveyed by legislative authorities, to manage and protect the Nation's natural resources. DOI resource protection responsibilities extend to lands and waters, fish and wildlife, and the Nation's cultural heritage. The DOI revised its Strategic Plan in 2003 with specific goals to improve the information base, resource management, and technical assistance needed for informed decision making. The DOI Strategic Plan aims to unify scientific knowledge with applications of that knowledge toward resource management through collaboration between scientists and Federal, State, Tribal and non-governmental natural resource managers. The DOI mission promotes informed Resource Protection, Resource Use, and Recreation, with the goal of Serving Communities to protect human health by advancing knowledge and strengthening decisions through the application of science. The United States Geological Survey's (USGS) Fisheries: Aquatic and Endangered Resources Program (FAER) supports the DOI Resource Protection Strategic Goals by providing scientific information critically needed to improve and sustain the health of freshwater, estuary and coastal biological resources.

2. U.S. GEOLOGICAL SURVEY (USGS)

The USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life. As the science agency for the DOI, the USGS is entrusted to provide unbiased, independent data and information on biology, hydrology, geology and geography to the Nation. The USGS has a primary responsibility to provide high-quality scientific data to the Department of the Interior and its Bureaus that oversee DOI lands and associated waters and aquatic resources.

3. USGS BIOLOGICAL RESOURCES DISCIPLINE (BRD)

Fundamental to the USGS mission is the goal of ensuring the continued availability of long-term environmental and natural resource information, by conducting systematic analysis and investigations to provide a scientific basis for natural resource problem solving and decision making. The USGS serves these functions though six Biological Resources Discipline science programs that are complemented by the Biological Informatics Program and the Cooperative Research Units Program. The core mission of the eight Biological Resources programs is to produce and make available to DOI natural resource managers and decision makers scientific information to support science-based conservation and restoration, management, and regulatory actions to sustain biological communities.

4. FISHERIES: AQUATIC AND ENDANGERED RESOURCES PROGRAM

The Fisheries: Aquatic and Endangered Resources Program (FAER) research support and technical assistance activities are conducted under the congressional authorizations that guide the USGS (Appendix B). The FAER Program provides high quality and objective scientific information to resource managers and the public. Capabilities include expertise in fisheries and aquatic biology, aquatic animal health, genetics and molecular biology, risk assessment and predictive modeling, biometrics, bioengineering, and geographic information systems. The FAER program coordinates with other USGS programs to provide integration of geological, geographical, and hydrological attributes of aquatic systems with biological information to allow analysis of aquatic resources on a watershed and landscape scale. The new FAER Program Strategic Plan focuses on the integration of program strategies with Bureau responsibilities and the DOI mission. Program research and technical assistance activities are primarily conducted to provide information for the Department's Resource Protection goals. This information also provides outcomes that are realized to fulfill DOI goals in Resource Use and Recreation, and Serving our Communities by providing sound science information that is provided for the health and well-being of the public.

a. HISTORICAL OVERVIEW

The Federal government assumed responsibility for the Nation's fisheries in 1871 when Congress created the U.S. Commission of Fish and Fisheries (USFC), the first Federal agency concerned with natural resource conservation. The National Fish Hatchery System was established at that time and in 1872 aquaculture was added to the Fish Commission's responsibilities. Results of USFC scientific studies on the nation's fisheries were first communicated to the public in the initial annual report on operations and research, published in 1873. The Commission of Fish and Fisheries was transferred to the Bureau of Fisheries in the Department of Commerce and Labor in 1903. In 1940 the Bureau of Fisheries and the Biological Survey joined together as part of the Department of the Interior's U. S. Fish and Wildlife Service (USFWS). Research scientists and facilities of the USFWS and other DOI bureaus were transferred to the newly created National Biological Survey (NBS) in 1993. The scientists and facilities of the NBS were transferred to the USGS in 1996 to form the Biological Resources Division. In 2003, the Fisheries and Aquatic Resources Program name was changed to the Fisheries: Aquatic and Endangered Resources Program to reflect a greater emphasis on science for the conservation and restoration of imperiled fishes, freshwater mussels, other aquatic organisms and aquatic habitats. The FAER Program, one of 29 Programs in the USGS, represents the aquatic species and aquatic habitat expertise within the Bureau.

b. PROGRAM REVIEW

The FAER program was last reviewed (1998) by a national panel of fisheries scientists representing the USGS, USFWS, Bureau of Land Management (BLM), Columbia Basin Fish and Wildlife Authority (CBFWA), the American Fisheries Society (AFS), Oak Ridge National Laboratory, and the University of Washington (UW). USGS scientists presented research activities in 12 specific areas of fisheries and aquatic resources research: physiology and behavior; health and disease; drug registration; culture and

propagation; life history; genetics and systematics; population dynamics and modeling; ecological and species interactions; faunal surveys and biodiversity; habitat requirements; habitat restoration, management and fish passage; and habitat assessment (see http://biology.usgs.gov/intranet/science/fish_recommendations.html). The review panel recommended increased science efforts in four areas that are reflected in existing FAER Program goals: the health of aquatic organisms and aquatic systems; biodiversity; species and habitat interactions; and restoration science. The Fisheries: Aquatic and Endangered Resources Program responded by redirecting research efforts toward expanded capabilities in molecular and cellular techniques to study biodiversity and aquatic macroinvertebrate ecology, and interdisciplinary studies to integrate biological and physical habitat information.

c. PROGRAM ACCOMPLISHMENTS

FAER Program scientists are recognized nationally and internationally in the areas of aquatic biological science including aquatic pathogens and diseases, fishery biology, fish behavior, fish passage, aquatic habitats, imperiled aquatic species, and restoration science. The expertise of FAER scientists is sought out regionally, nationally and internationally for consultations, research support, and technical assistance. FAER scientists are asked to participate in international studies on such topics as sturgeon and salmon biology, fish passage, fish diseases, and aquatic species and habitat relationships. Nationally, FAER scientists provide research support to over fifty Federal, State and Tribal fishery agencies, as well as non-governmental groups. Partner and customer requests and reimbursable support for USGS FAER scientific research support varies annually from $10M - 20M. Long established collaborative partnerships have been successful in addressing large and complex research initiatives associated with FAER Program goals. The following are examples that represent a broad overview of the Program's accomplishments.

Research for DOI partners:
Leetown Science Center (LSC) scientists have provided U. S. Fish and Wildlife Service fishery managers with studies and models of the effects of infectious disease on natural and cultured populations of fishes. The focus is on five priority pathogens: *Myxobolus cerebralis* (whirling disease parasite), infectious pancreatic necrosis virus (IPNV), infectious salmon anaemia (ISAV), and two species of Flavobacteria. Determinations of strain resistance, host specificity, environmental requirements and the development of diagnostic methods support the detection and management of diseases in fisheries of economic, recreational, and cultural importance.

Research for federal water management partners:
Columbia Environmental Research Center (CERC) research biologists have conducted interdisciplinary studies for the U. S. Corps of Engineers to assist in determining river management alternatives for conserving aquatic organisms in impounded rivers. Scientific data was collected on the population status, life history traits, behavior, critical habitat needs, reproductive requirements and available habitat for pallid sturgeon.

Integrated science:
Florida Integrated Science Center (FISC) biologists are participating in a complex of interdisciplinary studies in the Suwannee River basin and estuary that are needed to answer critical water resource and ecological issues. The influences of water availability, excess nutrient loading in ground water, and ground water and surface water interactions have been being investigated related to rare mussel species, the threatened Gulf sturgeon and manatee, fish and macroinvertebrate habitat suitability, and ecological function of the estuary. The study of Manatee Springs, one of several first-magnitude springs in the lower Suwannee River basin, is another integrated science effort that addresses serious human health and ecological concerns, key scientific issues concerning spring systems in Florida. In association with geophysical, hydrochemical and GIS information, biologists collected data that is being analyzed to examine patterns and trends in diversity, distribution, or abundance of subterranean, stygobiotic fauna that may be correlated with water-quality parameters, flow conditions, surface land-use activities, and other integrators of physical conditions as they relate to ecological responses in aquatic systems.

Emerging issues:
Native mussels are the most rapidly declining faunal group in the United States. Upper Midwest Environmental Science Center (UMESC) scientists have been leaders in performing quantitative assessments of unionid communities at many sites across the country. Data from six locations in a reach of the Upper Mississippi River is being used to perform statistical analyses using classification and regression trees to develop models to predict the presence or absence of unionids based on hydraulic, biological, and landscape variables. The role of fish hosts in structuring unionid communities is also being investigated. Field work to assess the accuracy of the hydroacoustic system to detect mussel beds in large rivers has been successfully completed. LSC scientists are also developing a normal flora bacterial database and a condition factor index for at risk native mussels. The ability to identify bacterial agents, compared across geographic areas and between mussel species, as a cause of a natural mortality will assist in ongoing relocation and restoration programs. This information provides resource managers with tools for health and disease inspections prior to relocation to prevent transmission of diseases to other populations of native freshwater mussels. LSC scientists are providing the USFWS with assessments of species composition, abundance, community structure and current status of unionid mussels in specific wildlife refuges.

Water availability:
Competing demands for water in the Upper Klamath Basin of Oregon has led to severe water quality problems and listing of Lost River and shortnose suckers as endangered in 1988. Western Fisheries Research Center (WFRC) researchers have been leaders on integrated research to determine population dynamics during seasonal water quality changes in Klamath Lake. In cooperation with the U. S. Fish and Wildlife Service, Bureau of Reclamation, local Tribes and water-user groups, USGS biologists and hydrologists have developed an integrated Science Plan for the Upper Basin and organized the Lower Klamath Basin Science Workshop in June 2004 to further coordinated research and management of the Klamath River basin for competing water needs and the restoration of aquatic resources.

Large rivers:
UMESC scientists have administered the Long Term Resource Monitoring Program on the Upper Mississippi River to collect data on how fishes of the Upper Mississippi River System respond to major land and river uses and management alternatives including commercial navigation, water-level changes, and ecosystem restoration. The research suggests that assumptions of habitat limitation may be unfounded. This research further underscores the need for integration of biology, hydrology, hydraulics and geomorphology to discover new options for the improved management of large rivers.

Fish passage engineering and physiology:
Conte Anadromous Fish Laboratory (CAFL) biologists have developed prototype multiple-species fish passage systems to assist managers in coordinated management of both migratory (Atlantic salmon, shad, eels) and resident species (sturgeon) that are affected by barriers. Biological evaluations of fishes under varied flow regimens, and testing of passage efficiency provide river and fish managers with guidelines for the design of efficient fish passage systems and the regulation of flows during critical migration or dispersal periods.

Molecular and genetic tool development assists managers of native and non-native fishes:
Alaska Science Center (ASC) scientists have developed rigorous genetic diagnostic systems to discriminate between spring and fall runs of salmon in the Columbia River, steelhead trout and char in the Kamchatka Peninsula, and cutthroat trout and rainbow trout in the Western states. The techniques allow further discrimination of gender, run and wild versus hatchery fish within species. These molecular genetic techniques allow non-lethal monitoring of at risk fish populations and assist managers in determining the origins, hybridization and interaction levels, and fates of native and introduced fish populations in mixed fisheries. Synthesis of the results on the evolutionary history of populations of at risk salmon from southern California to Alaska was used to determine colonization patterns across multiple habitat types, species interactions and introgression, and different life history strategies in relation to natural and anthropogenic habitat changes. The data are applied directly to questions of fish management, conservation, and restoration throughout the Pacific Ocean.

Aquaculture drug development:
UMESC scientists have employed innovative research techniques, e.g. the crop grouping concept, with a suite of specialized studies that are being applied to gain approval of therapeutants for public aquaculture. Crop grouping is a concept that species can be grouped by their temperature preference, activity level, and phylogeny. Expertise in toxicology, marker residue studies, target animal safety, and environmental assessments has recently been expanded to include new drug effluent modeling capabilities.

***Fish and aquatic organism disease research*:**
WFRC scientists have developed specialized diagnostic tools to allow the segregation of infected broodstock and their progeny in fish infected with bacterial kidney disease. The tools provide estimates of seasonal and annual modulations in the immune status of fish at different life stages and temperatures. This information was provided to fishery managers to assist in the development of better rearing and disease management practices.

International research:
The Great Lakes Science Center USGS Deepwater Science Program investigates a wide range of studies that focus on an array of complex habitat, fish, invertebrate, and mollusk related issues that are based on partner needs to conduct risk assessments and develop habitat restoration projects. Priority research needs in the Great Lakes as identified by the Great Lakes Fishery Commission, Canadian and U. S. natural resource managers have been addressed in studies that are assisting in the restoration of declining aquatic species in the Great Lakes. Lake trout restoration is major focus research area. Early mortality syndrome (EMS) is a pathology observed in the swim-up fry of lake trout, rainbow trout, coho salmon, and Chinook salmon. EMS is caused by a thiamine (vitamin B1) deficiency in the developing embryo. Thiaminase activity in forage fish, most notably alewives and smelt, was demonstrated to be a major factor contributing to the development of EMS. Factors that control or modulate thiaminase activity in the environment are now being investigated. Emerging diseases are another major focus in the Great Lakes. Virulence assessments of isolates of infectious pancreatic necrosis virus (IPNV), endemic and exotic to the Great Lakes basin, were conducted by FAER scientists supported by the Great Lakes Fishery Commission. Data critical to estimate the potential for adverse biological and/or economic consequences associated with introducing IPNV to watersheds of the Great Lakes basin, releasing IPNV-carrier cultured fish, or discharging virus-laden culture effluents was generated.

WFRC scientists developed and are validating microchemical techniques (strontium to calcium ratios in otoliths, otolith ageing and microstructure) to describe the chronology of migration in salmonids in the North Pacific including Alaska and Kamchatka, Russia. Controlled laboratory investigations with incremental increases in salinity from freshwater to salt water are providing validated models of strontium incorporation and salinity to help fishery managers monitor the migration of hatchery and native salmon between freshwater and marine habitats.

Aquatic species at risk:
CERC scientists employed ultrasonic telemetry and biologically-deployed remote sensing devices to determine pre-spawning, spawning migration, and post-spawning behavior of shovelnose sturgeon. Surgical implantation of data storage tags provided temperature and depth readings every 15 minutes. These data provided fishery managers with detailed information about the location, seasonal distribution, and preferred habitat of imperiled sturgeon to assist in the development of life history-based, ecologically sound restoration plans in managed rivers.

MISSION

The mission of the **USGS Fisheries: Aquatic and Endangered Resources Program** is to work with DOI partners and other natural resource managers to provide the scientific understanding and technologies needed to support sound management and conservation of our Nation's aquatic biological resources.

The FAER Program research mission is to provide critical scientific information that supports the Department of the Interior goal to protect and preserve the Nation's natural and cultural resources. Research data, technologies, and models are applied by natural resource managers and decision makers in designing and implementing conservation and restoration plans to manage natural resources for a healthy environment and strong economy.

1. SCIENCE PLANNING STRATEGIES

The FAER Program develops research projects for partners and customers to support sound management and decision making through a systematic approach that includes five science planning strategies.

a. Organize and facilitate workshops, meetings, and discussions with collaborating scientists, cooperating agencies, partners, customers, and stakeholders to define and prioritize scientific questions for systematic analysis.

b. Formulate hypothesis-driven research plans with other USGS programs and partner agencies to answer specific science information needs and develop implementation plans and funding approaches.

c. Conduct systematic analyses and assessments in response to needs to build a scientific basis for adaptive natural resource management decisions. These analyses emphasize the biological attributes of aquatic species and the interaction of these species with their habitats in response to natural ecological functioning or human activity.

d. Develop and test new research techniques and technological tools, incorporating and applying these to research designs, data collection and analysis, syntheses and models to provide advanced scientific information and assessment tools to resource managers.

e. Synthesize existing biological and physical information for aquatic species and habitat interactions to develop synoptic conceptual and statistical models for population or habitat productivity, viability analysis, risk assessments, and decision support tools for natural resource managers and decision makers.

f. Timely transfer of scientific information and products to natural resource managers and decision makers to improve the information base for aquatic communities and habitats.

2. RESEARCH AND TECHNICAL ASSISTANCE CAPABILITIES

a. RESEARCH

The FAER Program offers a unique suite of scientific and information capabilities that enable the USGS to address the Nation's aquatic resource questions in the areas of aquatic organism biology; health and diseases; ichthyology; genetics and molecular biology; behavior; ecology of aquatic populations and aquatic habitats; restoration of aquatic habitats; and recovery and conservation of aquatic species. The FAER Program conducts research on inter-jurisdictional aquatic resources that contributes toward management for the conservation, restoration, and sustainability of large aquatic systems including rivers, lakes, estuaries, and near shore areas. Aquatic species, including fishes, aquatic microorganisms, aquatic invertebrates, other water dependent species are investigated to understand the life history and habitat requirements of newly identified and at risk species. This information is needed to anticipate and manage invasive, exotic and introduced aquatic species that may compete with native species. The FAER Program, in providing the Bureau with expertise in aquatic organism and aquatic system health, is closely aligned with other Biological Resource Programs: Invasive Species; Contaminant Biology; Terrestrial, Freshwater and Marine Ecosystems; Status and Trends of the Nation's Biological Resources; Wildlife: Terrestrial and Endangered Resources; Biological Informatics; and the Cooperative Research Units. The complex nature of aquatic resources requires the complementary capabilities of other USGS Water, Geology, and Geography discipline programs, most notably: the Ground Water Resources; National Water Quality Assessment; National Streamflow Information; Coastal and Marine Geology; and Geographic Analysis and Monitoring programs.

b. TECHNICAL ASSISTANCE

Short-term, rapid response technical assistance provides timely results to answer science needs in emergency or acute situations. The call for quicker response to DOI needs for scientific information has been addressed by development of a separate goal to provide short-term research support and technical assistance for tactical management needs. Examples include identification of newly emerging aquatic organism diseases, identification and control technologies of invasive aquatic species, forensic identification of imperiled species, and investigations of abrupt degradation of aquatic habitats through natural catastrophic or human induced events. Technical assistance activities may develop into long-term research if scientific uncertainty prohibits immediate action by natural resource managers or decision makers. Short-term targeted research complements long-term monitoring, research, and modeling activities that increase our understanding of the complex community dynamics of large aquatic ecosystems such as the Great Lakes, large rivers, estuaries, and coastal zones.

c. RESEARCH INFRASTRUCTURE

FAER research activities are conducted primarily at ten of the Biological Resources Science Centers, their laboratories, field stations, and cooperating academic institutions. Science facilities are located throughout the United States (Figure 1) and include research laboratories, a Level III biological containment facility, a fish passage engineering facility, and numerous satellite laboratories and field stations.

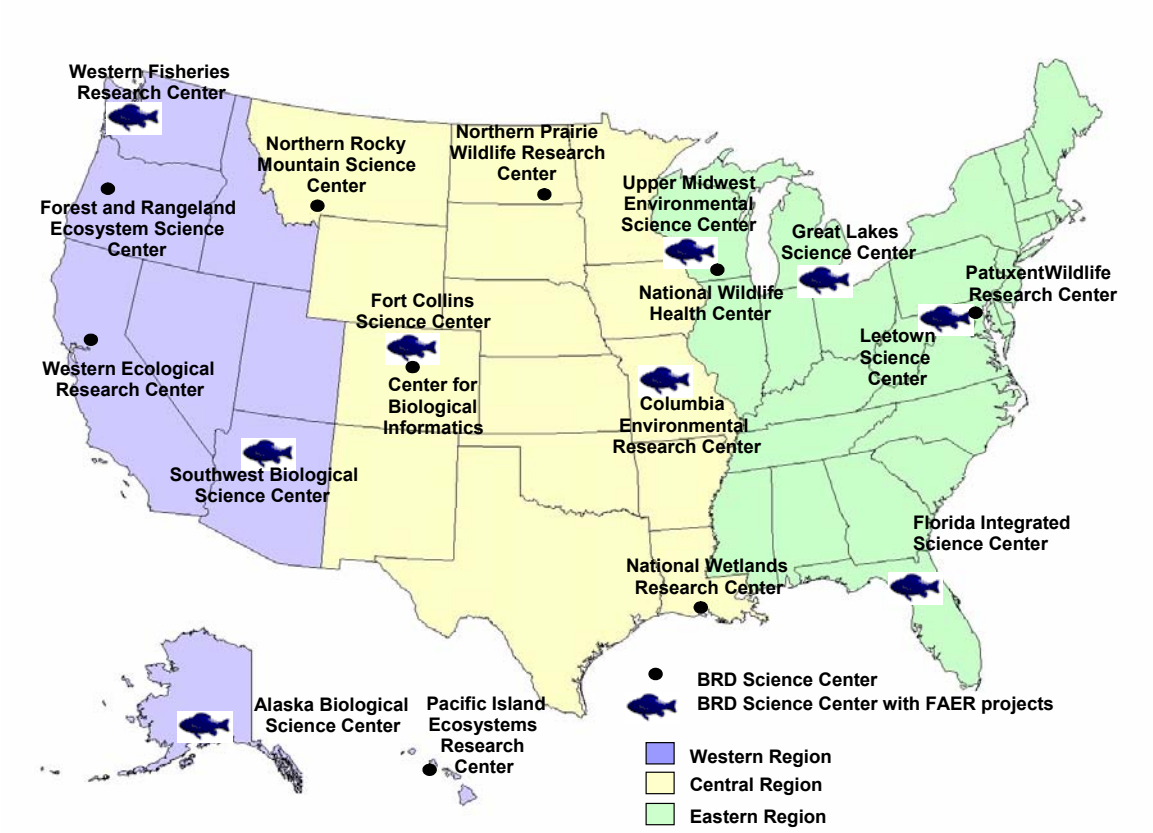

Figure 1. USGS Biological Resources Research Centers

Specialized laboratories and unique methods that have been developed or adapted for fishes, aquatic organisms and aquatic environments are applied in systematic analyses that provide the scientific basis for solutions to natural resource management questions. Research activities often involve *in situ* field work that requires sophisticated biotechnologies such as remote sensing, hydroacoustics, electronic tagging and tracking, sonar and radio telemetry. Deep water vessels allow sampling, analysis and monitoring in reservoirs and large lakes across the Nation. Other specialized methods permit research in high altitude tributaries and main stem rivers to estuaries, and near-shore habitats. The USGS website provides access to information on FAER Program activities (http://biology.usgs.gov/farp/index.htm) and BRD Science Centers (http://biology.usgs.gov/pub_aff/centers.html).

3. SCIENCE QUALITY

Rigorous scientific data and information are the primary products of the FAER Program. Under the Department of the Interior guidelines for government data and information, the Program is committed to objectivity, utility and the integrity of the scientists, projects, and products and outcomes. The DOI Code of Scientific Conduct and USGS Science Quality Policy establish an organizational framework and common procedures for scientific data and information to insure uniform standards and unbiased, independent peer reviewed products.

4. PRODUCTS AND SCIENCE INFORMATION TRANSFER

FAER Program scientists provide research support and scientific information to DOI bureaus, other Federal, State, Tribe and non-governmental natural resource managers and decision makers through a wide range of products: systematic analyses and assessments; data and databases; peer reviewed, published reports and publications; models; decision support tools; risk assessment models; geographic information systems; and other advanced electronic information systems. Program scientists also provide syntheses of biological, hydrological, and physical data from site-specific, regional and national research activities to evaluate watershed- and population-scaled effects. The goal for science information transfer is to provide accurate and timely science-based information to our partners, customers, policymakers and the public to support balanced natural resource management to protect, conserve and restore the Nation's aquatic resources. The FAER Program will work closely with the new Fisheries and Aquatic Resources Node of the National Biological Information Infrastructure to provide better access to the fishery and aquatic databases and products of the FAER Program.

CHALLENGES AND DIRECTIONS FOR THE FUTURE

Aquatic habitats are subject to constant environmental change, therefore multidisciplinary approaches are needed to ensure our understanding of the interactions between aquatic animals and aquatic habitats. The greatest challenge is to ensure a complete understanding of the effects of landscape-scaled change on local, regional, watershed and ecosystem levels of aquatic communities. A further challenge is the integration of biological information in the context of geologic, hydrologic, geographic and climatologic change, a priority FAER Program focus. The FAER Program will focus on the following major research areas identified by partners and customers as current and future priorities and described by the thematic science goals in Table 1. To maintain a flexible program that can meet ever-changing natural resource management needs, specific objectives and detailed strategies were developed to meet these goals. Goals, objectives, and strategies for success are found with corresponding outcomes and measures in Table 2.

Priority actions for the FAER program include:

1. Provide scientific information about the ***diversity, life history and species interactions*** that affect the condition and dynamics of aquatic communities. New molecular tools will be incorporated into systematic analyses to provide quality data to develop population viability analyses, limiting factor determinations, and models for population and community viability, resilience and recovery.

2. Provide scientific information about factors and processes that affect ***aquatic organism health*** in support of survival, protection, conservation and recovery. Identification of organisms and environmental factors that contribute to the occurrence of infectious diseases of aquatic organisms will contribute to the understanding of the scientific consequences of poor aquatic animal health and disease on populations of aquatic organisms and the function of aquatic communities within aquatic habitats.

3. Quantify and describe functional relationships among ***aquatic species and aquatic habitats*** to determine how habitat influences life history and productivity, to provide information to conserve or restore aquatic community structure and function.

4. Provide science support for natural resource managers by identifying and quantifying the factors that limit populations of ***aquatic species at risk.*** Population viability analyses and models for species recovery will help evaluate the effectiveness of management efforts to recover imperiled aquatic species and aquatic habitats.

5. Develop research and technology tools to provide the scientific basis for developing and evaluating the effectiveness of adaptive management strategies for ***restoration*** efforts to sustain aquatic resources.

6. Provide ***research support and technical assistance*** to DOI bureaus, other Federal and State government agencies, Tribes, and non-governmental organizations to support natural resource management problem solving and decision making by providing timely, responsive, cost effective, and scientifically credible products.

The FAER Program has prepared out-year initiatives that address USGS Future Science Directions found in the Bureau Planning Model: Ecosystem, Health, Sustainability, and Land Surface Change; Invasive Species; Ground Water Resources; Rivers; and Coastal Environments. Water availability and its effects on natural and human systems are the most critical regional and national issues and are addressed in the DOI Water 2025 Initiative. Water availability is directly related to the management of aquatic habitats and aquatic organisms. Program scientists developed proposals for the Connecticut and Suwannee Rivers, where urbanization, water withdrawals, diversions, or impoundments are affecting water availability, water quality, aquatic species, and aquatic habitat. The initiatives are targeted at systems that can serve as reference models for integrated studies and aquatic species that are affected nation wide (sturgeon). A broadening of basic research from the laboratory to the landscape has taken place to provide new innovative research and advanced technologies to support the restoration and sustainability of aquatic resources across the Nation.

TABLE 1. FAER 5-YEAR PROGRAM GOALS

Fisheries: Aquatic and Endangered Resources Program Goals
GOAL 1. DIVERSITY, LIFE HISTORY AND SPECIES INTERACTIONS OF AQUATIC ORGANISMS *Provide scientific information about the **diversity, life history and species interactions** that affect the condition and dynamics of aquatic communities.*
GOAL 2. AQUATIC ORGANISM HEALTH *Provide scientific information about factors that affect **aquatic organism health** in support of survival, protection, conservation and recovery.*
GOAL 3 AQUATIC SPECIES AND HABITAT INTERACTIONS *Quantify and describe functional **relationships among aquatic species and habitats** to provide information to conserve or restore aquatic community structure and function.*
GOAL 4. AQUATIC SPECIES AT RISK *Provide science support for natural resource managers by investigating the factors that contribute to the conservation and recovery of **aquatic species at risk**.*
GOAL 5. RESTORATION SCIENCE FOR AQUATIC SPECIES AND AQUATIC HABITATS *Develop research and technology tools to provide the scientific basis for developing and evaluating adaptive management strategies to sustain aquatic resources.*
GOAL 6. RESEARCH SUPPORT AND TECHNICAL ASSISTANCE TO AQUATIC RESOURCE MANAGERS *Enhance research capabilities to **provide research support and technical assistance** to DOI bureaus, other Federal and State government agencies, Tribes, and non-governmental organizations for application in natural resource management problem solving and decision making.*

TABLE 2. FAER GOALS, OBJECTIVES, STRATEGIES, OUTCOMES AND MEASURES

FAER goals and objectives provide well defined program approaches, from which strategies are developed annually, based on the needs identified by partners and customers. The timeline for completion of these identified needs (systematic analyses, assessments, data releases and information transfer) for individual strategies is determined by the scope and complexity of the activities, and may involve annual, two-to-three year, or longer-termed life history-based or ecological milestones. FAER program outcomes and performance measures support DOI Resource Protection goals and strategies, in particular 2.1, 2.2, and 2.3. FAER Program activities also provide measurable outcomes for other DOI goals and strategies including Resource Use 5.2, 5.3, 5.4 and 6.3; Recreation 1.1; and Servicing Communities 2.1.

Goal 1. Diversity, Life History and Species Interactions of Aquatic Organisms *Provide scientific information about the **diversity, life history and species interactions** that affect the condition and dynamics of aquatic communities.*		
Objective 1A: Develop population viability analyses, limiting factor determinations, and models for population and community viability, resilience and recovery.		
Strategy	**Outcome**	**Measure**
1A1. Develop life history based population models for fish and other aquatic organism species and validate the models with case histories to evaluate current and potential carrying capacity.	• Improved understanding of complex aquatic life histories of anadromous, catadromous, and resident fishes and aquatic microbes, invertebrates, crustaceans, and mollusks.	• Natural resource managers apply the life history long-term data as a framework to coordinate multi-species management in complex aquatic communities.
1A2. Conduct life history and population studies of imperiled populations of fishes and other aquatic organisms to develop viability analyses.	• Provide life stage, temporal and spatial population data and viability analyses.	• Data are delivered annually are used as references for recovery goals. • Viability analyses are applied by managers. • Resource managers develop achievable recovery objectives.

1A3. Develop risk assessments to determine the impacts of environmental stressors and contaminants on fish and aquatic organism health and diversity.	• Risk factors are identified, and consequences of impacts are transferred to natural resource managers.	• Natural resource managers cite risk factors and recommended measures for mitigation in management plans. • Managers use risk assessments models to predict population and community effects.
1A4. New: Identify the factors that limit the abundance and production of key fishes and other aquatic species that face environmental or human disturbance in large rivers.	• Systematic analyses of biological, physical and chemical factors that limit aquatic populations are conducted in response to resource managers requests.	• Data from systematic analyses are transferred to resource managers to improve the information base for decision making to sustain biological communities in large rivers.
1A5. New: Determine the mechanisms governing recruitment and recovery of key fish species in large lakes and determine the geographic scope of recovery.	• Conduct research, collect data, and conduct assessments of fishes in lakes to sustain their populations and aid recovery.	• Resource managers use assessments and datasets to manage important fish species in large aquatic systems.
Objective 1B: Evaluate community dynamics and food webs in aquatic systems.		
Strategy	**Outcome**	**Measure**
1B1. Determine the effects of biogeochemical and physical processes (water quality, hydrology, climate change, forage and invasive species) on the distribution and abundance, food base and trophic dynamics of fishes and other aquatic organisms.	• Improved information base of species structure, abundance, and diet. • Development of conceptual models of aquatic communities with respect to hydrology, water quality, primary productivity, invertebrate abundance, flows, sediments, and salinity. for assessments and programs	• Establishment of long-term data collections and programs that facilitate scientific assessments and evaluations that determine the effects of changes in aquatic systems on the trophic dynamics of aquatic communities.
1B2. Determine freshwater, estuarine, and coastal fish community assemblages, population status, and habitat usage at different life stages in relation to physical processes.	• Improved understanding of multi-spatial and temporal factors that affect aquatic community structure and the connectivity between freshwater-marine habitats.	• Improved information base of the freshwater-marine interface facilitates coordinated, landscape-scaled management of aquatic resources.

1B3. Determine the ecological effects of artificial aquatic habitats, (e.g. impoundments, withdrawals and other water management techniques) on natural aquatic systems and the persistence, dispersal or colonization of native, introduced, and invasives aquatic organisms and fishes.	• Scientific assessments and descriptive models are provided to natural resource and water managers.	• Managers use models to improve the allocation of water for the sustained economic and ecological benefits of aquatic systems.
1B4. Conduct experimental studies of population growth and predator-prey interactions in fishes and other aquatic organisms to determine density dependent factors critical to aquatic community persistence.	• Identification of density dependent factors to facilitate management to sustain aquatic communities.	• Systematic analyses and assessments delivered to resource managers to improve management of aquatic resources.
Objective 1C: Develop and integrate new genetic, molecular and biological tools into systematic analyses.		
Strategy	**Outcome**	**Measure**
1C1. Develop and apply advanced techniques to conduct rigorous genetic analyses of individuals and populations, synthesize spatial and temporal information on the evolutionary history, colonization patterns, species interactions, and genetic introgression in populations and species of concern.	• Tools are developed to investigate the diversity in fishes and other aquatic organisms to assist natural resource managers in delineating populations (e.g. Evolutionarily Significant Units [ECUs]). • Molecular tools to resolve taxonomic questions at multiple levels.	• Long-term data sets of genetic characteristics of aquatic species with predictive models that describe the potential risks and outcomes of conservation and restoration efforts are provided to managers.
1C2. Apply genetic techniques to identify spatial markers of population structure that can be used to estimate fish movements in relation to barriers.	• Scientific assessments that describe the effects of changes in hydrologic connectivity on aquatic organism population structure.	• Use of genetic markers delineates populations of important aquatic species to improve management of aquatic species in relation to barriers.

1C3. Develop and demonstrate the use of genetic and molecular tools in species conservation and recovery for natural resource managers	• Assessments tools for adaptive management of native and imperiled species.	• Managers provided with new tools for population assessments and evaluations of new management practices.
1C4. New: Explore genetic means of sex determination and manipulation to control invasive species in aquatic systems.	• Systematic analyses and assessments delivered to natural resource managers to control invasive species.	• Demonstrated application of genetic tools in invasive species identification and management.
1C5. New: Develop new investigations of the function of gene expression with accompanying bioinformatics databases to synthesize and apply molecular genetics information on gene function and expression.	• Extrapolation of organismal biology to populations and species evolution. • Demonstrations of how regulatory gene networks evolve and differ among populations of closely related species.	• New information and assessment tools for the scientific management of aquatic resources based on biological function.
Goal 2. Aquatic Organism Health *Provide scientific information about factors that affect* ***aquatic organism health*** *in support of survival, protection, conservation and recovery.*		
Objective 2A: Characterize the normal physiological, biochemical and homeostatic capacities of aquatic organisms in their environment to define the baseline capacity of aquatic organisms in natural habitats.		
Strategy	**Outcome**	**Measure**
2A1. Conduct complex health assessments of fish and aquatic organisms, as indicators of population, community and habitat health.	• Development of standard health assessments and reliable indicators of aquatic species and system health. • Models of pathogens, hosts, intermediate hosts, habitat, and critical environmental factors and interactions that facilitate or control infectious disease in aquatic animals and aquatic habitats.	• Accessible databases of descriptors of aquatic animal health for informed prevention or control of diseases to sustain aquatic communities. • Increased understanding of the scientific consequences of poor aquatic animal health and disease on populations of aquatic organisms and the ecological function of aquatic systems.

2A2. Investigate the physiological and biochemical mechanisms underlying an organism's response to pathogens, and the influence of environmental stresses on physiological, immunological, and biochemical responses.	• Disease models that simulate hydrologic and substrate characteristics affecting disease transmission and outbreaks based on aquatic pathogen life history traits, habitat requirements and interactions of aquatic pathogens and parasites with fish and other aquatic organisms.	• Improved predictive and real time management of chronic and acute disease in aquatic organisms and aquatic systems. • Identification of factors in fish culture that affect the initiation and progression of infectious diseases, and lead to poor fish quality and mortality.
2A3. Assess indicators of normal immune function in salmonids and other aquatic species with new generation tools (e.g. microarrays and quantitative PCR).	• Increased understanding of the biological basis of disease in aquatic organisms. • Establish of baseline data for studies on enhancement (e.g. vaccination) or suppression (e. g. by contaminants) of the fish immune system.	• Improved scientific tools for the management of disease in aquatic species.
Objective 2B: Identify environmental stressors that affect aquatic organism health and performance.		
Strategy	**Outcome**	**Measure**
2B1. Conduct studies to assess effects of multiple stressors at the organism and population level, including assessment of the synergistic effects of stressors (e.g. environment, temperature, natural toxins, contaminants, metals, infectious agents.	• Improved understanding of multiple, cumulative, and synergistic effects of stressors on aquatic species. • **New:** Determine the biological consequences of and relationship between contaminants interacting with multiple environmental factors on aquatic animal health using biomarkers and other molecular tools.	• Improved viability and risk assessment models provided to resource managers based on expanded systematic analyses, increased number of measured variables, advanced molecular tools, and larger data infrastructures to provide landscape-scaled analysis.
2B2. Determine the effects of impoundments and by-pass systems on the disease status of fish populations.	• Improved understanding of the effects of barriers on the biology of aquatic organisms.	• Scientific assessments provide recommendations to resource managers for mitigation of effects of barriers to sustain aquatic species and aquatic habitat ecological function.

2B3. New: Development of studies to assess the effects of global change on the spread of aquatic pathogens and aquatic organism health.	• Expanded temporal and geographic scope of systematic analyses of pathogens and diseases, and epidemiological assessments and models.	• Improved multi-jurisdictional management of disease in aquatic organisms and aquatic systems.
2B4. New: Conduct research to address the effects of pharmaceuticals, and personal care products in water on fishes, aquatic organisms and habitats, and human health.	• Scientific assessments improve the information base for management of aquatic effluents to improve the health of aquatic organisms and protect human health.	• Natural resource and human health entities have improved information base for watershed management to ensure aquatic community and system health, and protect human health.
Objective 2C: Identify organisms and factors that contribute to the occurrence of infectious diseases of aquatic organisms.		
Strategy	**Outcome**	**Measure**
2C1. Study the genetics and epidemiology of infectious aquatic pathogens, intermediate hosts, and the genetics of hosts and pathogens to improve diagnostic and control methods.	• Improved diagnostic methods and control of disease in aquatic organisms. • Development of molecular probe technologies and methods to distinguish virulent/non-virulent strains of pathogens.	• Conceptual models developed for managers to predict, track, and control disease outbreaks. • Standardized diagnostics techniques to assess disease status in aquatic organism and aquatic systems.
2C2. Determine the heritability of disease resistance and immune function in fishes and other aquatic organisms.	• Improved understanding of genetic basis of disease in aquatic organisms.	• Improved management of disease in aquatic organisms.
2C3. New: Study factors controlling the distribution and severity of fish disease making use of advanced genetic and molecular tools to provide novel insights into factors affecting the distribution and evolution of viral, bacterial and parasitic pathogens of fish.	• Expansion of long-term disease datasets with genetic and molecular factors to detect or diagnosis, treat, and control disease in aquatic organisms.	• Data are used in management of disease in important aquatic resources.

Objective 2D: Develop novel techniques, tools and strategies to improve and promote the health and survival of aquatic organisms for conservation, restoration, and public fisheries.		
Strategy	**Outcome**	**Measure**
2D1. Conduct research to address requirements of regulatory agencies to gain broad approval of urgently needed medicinal drugs and chemicals to support fish health management plans for public aquaculture.	• Reliable and efficacious tools and methods to control or prevent disease in public aquaculture or in imperiled aquatic organisms and fishes.	• Completed technical sections that enable drug sponsors to support the broad use of therapeutants in public aquaculture. • The development of safe and effective aquaculture drugs for use in public aquaculture.
2D2. Develop, validate, and apply analytical methods to detect chemicals, pharmaceuticals, and aquaculture drug residues in water, sediments and aquatic organisms.	• Tools and methods to detect and assess toxicological effects of chemicals, aquaculture drugs and pharmaceuticals on aquatic animal and human health.	• Analytical methods for priority aquaculture drugs that are applied to support human food safety, efficacy, animal safety, regulatory reconnaissance, and future drug research. • Drug discharge models that support environmental assessments for new aquaculture drugs and aquaculture facility discharge.
2D3. New: Develop models of biological, chemical, and physical factors controlling the distribution and severity of fish disease and application of models to evaluate management alternatives.	• Development of protocols for quarantine methods to minimize the transfer of aquatic disease during relocation or restoration of aquatic animal populations. • Disease transmission models that can be used to manage disease in aquatic communities on different spatial scales.	• New assessment tools for the prevention and control of disease in aquatic species and aquatic systems.

Goal 3. Aquatic Species and Habitat Interactions *Quantify and describe functional* ***relationships among aquatic species and habitats*** *to provide information to conserve or restore aquatic community function.*		
Objective 3A: Determine how physical and ecological processes build and sustain aquatic habitats, and habitat influences life history and productivity.		
Strategy	**Outcome**	**Measure**
3A1. Examine the relationships between biotic and abiotic factors of aquatic habitat, fish assemblages and aquatic community structure.	• The structure and function of aquatic systems at or near equilibrium are defined.	• Assessments that provide resource managers with an estimate of the amount of disturbance that can be absorbed during different management actions.
3A2. Determine the length of residence and growth of fishes and other aquatic organisms in lakes, streams, rivers, estuaries, and coastal or tidal areas to determine the importance of near shore areas and estuaries to different life stages of aquatic organisms.	• Expanded understanding of the importance of specific aquatic habitat types on the viability and productivity of aquatic populations.	• Resource manager have information to develop life history and multi-species based management plans to sustain important aquatic species and their critical habitats.
3A3. Conduct interdisciplinary studies of the biology, ecology, and hydrology of groundwater sources (springs, etc.) to support water management and to sustain aquatic populations.	• Improved understanding of the complex dynamics of aquatic communities and aquatic habitats.	• Aquatic systems in transition are identified and biological and physical reference data is available for development of informed management strategies.
3A4. Determine the effects of natural and human induced changes, and remedial measures on aquatic species and habitat interactions	• Scientific assessments of the impacts of floods, droughts, fires, diversions, withdrawals, impoundment, channelization, woody debris, agricultural run-off, and industrial discharge on aquatic resources.	• Improved information base for resource managers for watershed-scaled management to sustain aquatic communities and habitats. • Assessments of the benefits of enhanced connectivity between different aquatic habitats on aquatic populations.

3A5. New: Identify preferred habitat for key river fishes and determine how alterations to habitat might affect life history, species assemblages, and productivity of those species in large rivers.	• Expanded datasets of watershed and aquatic habitat variables and effects on aquatic species. • Expanded in-depth characterization of previously unknown limiting effects of environmental factors on aquatic communities.	• Assessments and tools for managers to predict the effects of natural and anthropogenic changes in watersheds on aquatic species and aquatic habitats.
Objective 3B: Investigate and model energy dynamics, trophic dynamics and food webs in lakes, rivers, estuaries and coastal waters.		
Strategy	**Outcome**	**Measure**
3B1. Document aquatic community dynamics in reservoirs and major tributaries to describe the abundance and distributions of fish in relation to trophic dynamics and aquatic habitats in impounded systems.	• Predictive geospatial information system models for trophic relationships among aquatic species in impounded systems.	• Managers apply multi-species models for management of aquatic resources in managed systems.
3B2. Conduct nutrient assessments in watersheds to document levels in streams and rivers to test the efficacy of nutrient management as a restoration tool for anadromous salmonids.	• Determine indicators of nutrient enrichment and nutrient sources and sinks in aquatic habitats. • Protocols for nutrient enrichment are developed for different streams, rivers, and species.	• Resource managers have new science-based tools to improve the productivity and restoration of important fish populations.
3B3. New: Develop heuristic numerical models of the response of river and lake food webs to changes in hydrology, hydraulics, climate, and river and lake management practices.	• Models identify critical food-web links and test hypotheses about responses of food webs to natural and man-made disturbances. • **New:** Operational models of the response of food webs to natural disturbances or aquatic habitat restoration activities.	• Models of community dynamics under different disturbance regimes are available to managers to develop effective programs to sustain aquatic communities. • Improved information base on changes in fish populations in response to hydrologic variation.

Objective 3C: Measure the response of aquatic species and aquatic systems to natural and human induced changes.		
Strategy	**Outcome**	**Measure**
3C1. Determine the broad-scale environmental variables that affect different life stages of declining anatropous fish populations in the climatic extremes of high northern latitudes.	• Persistent datasets to improve information base to improve landscape-scaled management of aquatic communities.	• Improved science information base for the management of imperiled fishes.
3C2. Monitor changes in fish, soft-sediment macro invertebrates, aquatic plants, water quality, and land cover in large impounded river systems.	• Long-term resource monitoring programs and long-term data collections to improve watershed-level management of aquatic resources. • Improved information base on the behavior of sturgeon and other imperiled species in managed rivers.	• Improved information on the effects of dredging, near hydroprojects and fishways on population status, distribution, dispersal and migration. • Informed resource management decisions on managed rivers to sustain biological communities.
3C3. Develop methodologies for constructing population and community dynamics models from field data.	• Expanded long-term and persistent datasets on food sources, competitors, predators, and physical surroundings including anthropogenic alterations.	• Scientific assessment tools available to managers for informed resource management.
Objective 3D: Evaluate and predict natural and human impacts on aquatic communities.		
Strategy	**Outcome**	**Measure**
3D1. Develop predictive models of responses of the major biota of large rivers to management alternatives and natural changes.	• Application of data from long-term resource monitoring programs to development of management alternatives.	• Science-based, informed resource management decisions for coordinated, watershed level management of aquatic resources.

3D2. Estimate fish behavior, condition, and survival in naturally disjunctive, fragmented, or engineered systems.	• Validated methods (e.g. telemetry) to measure factors contributing to fish survival at barriers. • Quantification of effects of barriers, guidance and fish passage structures on fish behavior and survival.	• Increased effectiveness of management measures to improve fish survival in engineered structures or at barriers (e.g. turbines, spillways, sluiceways).
3D3. Evaluate the effects of different fish sampling, monitoring and tagging methodologies on fish health and performance.	• Systematic analyses and investigations of research and monitoring methodologies as defensible management tools.	• Managers are provided with products to improve monitoring and assessments for program management.
3D4. New: Develop predictive models and decision support systems to evaluate the effects of management alternatives and natural changes on aquatic species and communities.	• Predictive models and decision support systems to evaluate the effects of management alternatives.	• Improved management programs and alternatives for the restoration of aquatic species.
3D5. New: Develop predictive models of aquatic species and community interactions under different environmental disturbance regimes or invasive species.	• Predictive models and decision support systems to evaluate the effects of management alternatives.	• Improved management programs and alternatives for strategic planning for the conservation or restoration of aquatic species.

Goal 4. Aquatic Species at Risk *Provide science support to natural resource managers by investigating the factors that contribute to the conservation and recovery of* ***aquatic species at risk****.*		
Objective 4A: Identify and quantify the factors that limit populations of aquatic species at risk.		
Strategy	**Outcome**	**Measure**
4A1. Investigate the status, condition, distribution, environmental requirements and threats to at risk fishes and invertebrate populations and their aquatic habitats.	• Understanding of correlation of limited fish distributions and occurrence with microhabitat requirements. • Characterization of limiting factors that threaten sustainability.	• Data to support population viability analysis and recovery plans. • Data to support development of Habitat Conservation Plans.
4A2. Describe genetic, life history, and competitive differences among native, introduced or invasive species.	• Systematic surveys of native species to collect biological information to measure rates of population change. • Investigations of food and oxygen consumption rates of genetically distinct populations of imperiled fishes to determine the effects of barriers to fish passage on fish condition.	• Improved information for the development of adaptive management actions to conserve or restore native species. • Improved information for multi-species management and conservation and restoration of at risk species. • Development of conservation methods that target specific life history stages or behavior.
4A3. Develop geographic information system (GIS) frameworks to explore potential causal relations between the distribution of native species and a suite of physical and biological variables, measured across broad geographic areas.	• Improved datasets of biogeochemical characteristics of rivers, lakes, watersheds, estuaries or coastal near shore areas related to aquatic organism distributions.	• GIS tools for managers for the scientific assessment of biological communities.

4A4. New: Determine the effects of modifications in watersheds or channels on the ecology and life history of at risk anadromous, catadromous, and amphidromous fishes including endangered or threatened species.	• Improved data on the spawning, rearing, migration and survival of at risk species for development of adaptive land and watershed management programs.	• Methods for population assessments and predictive tools for population trajectories to aid aquatic community management.
Objective 4B: Develop scientifically defensible methods for at risk and rare species to determine population status and response to management actions.		
Strategy	**Outcome**	**Measure**
4B1. Determine genetic patterns in the geographic structure of at risk native fish and aquatic organism populations throughout their ranges.	• Data on preferred, critical and optimal habitat for at risk species.	• Defined environmental and habitat parameters for management of at risk species.
4B2. New: Develop genetic databases with quantification of geographic variation of genetic structure within species, of dispersal and population fragmentation.	• Improved understanding of phylogenetics of at risk species and populations.	• New management tools for conservation and restoration of at risk species.
4B3. New: Evaluate the effectiveness of new technologies to locate, map and assess the status of aquatic populations in lakes, rivers, estuaries, and coastal near shore areas in relation to biological, chemical and physical factors.	• Improved genetic marking methods to identify eggs, larvae and gender of at risk species**.**	• New management tools for conservation and restoration of at risk species.
4B4. Development of models to analyze monitoring data and project population recovery given alternative management strategies.	• Develop specific population viability analyses and models for species recovery.	• Enhanced efforts to conserve at risk species with predictive models that allow managers to estimate extinction risk.

Objective 4C: Evaluate the effectiveness of management efforts to recover imperiled aquatic organisms and habitats.		
Strategy	**Outcome**	**Measure**
4C1. Develop scientific methods to evaluate and measure the effects of invasive species and their effects on at risk fishes and other aquatic organisms.	• Risk assessment methods and models for the characterization of invasive species interactions with at risk species.	• Predictive models for managers for avoidance and mitigation of invasive species effects on at risk species.
4C2. Examine the full array of biological and chemical control options for invasive pathogens, fishes, and other non-native aquatic organisms in freshwater and marine waters.	• Development of biotechnology and bioengineering solutions to control or eradicate aquatic invasive species that threaten at risk species.	• New tools for managers to conserve at risk species.
Goal 5. Restoration Science of Aquatic Species and Aquatic Habitats *Develop research and technology tools to evaluate the scientific effectiveness of adaptive management strategies for* ***restoration*** *efforts to sustain aquatic resources.*		
Objective 5A: Provide the scientific reference measurements and tools to determine biological goals for the restoration of fishes, aquatic macroinvertebrates and other aquatic species, aquatic habitats, and the ecological functions of aquatic systems.		
Strategy	**Outcome**	**Measure**
5A1. Provide evaluations of species diversity and status of aquatic species.	• Simulation models to determine aquatic community goals for restoration.	• Scientific guidance for conservation and management to restore and maintain target species and their required habitats.
5A2. Develop, refine, and apply methods to estimate abundance and study the role of patchiness and interface habitats as refuges for different life stages of rare organisms.	• New simulation models with applications of historical, ecological datasets to describe links between natural processes and anthropogenic habitat alteration and effects restoration efforts.	• Improved science-based restoration programs.
5A3. Develop models that identify physical factors, stressors, interactions, indicator species and pathways that drive change in aquatic systems.	• Conceptual models for species recovery are developed using long-term datasets.	• Decision support tools for improved management decisions on restoration of aquatic species and aquatic habitats.

Objective 5B: Develop restoration and reestablishment techniques.		
Strategy	**Outcome**	**Measure**
5B1. Develop and evaluate techniques to permit conservation, relocation, reintroduction and recovery of declining, threatened, and endangered fishes, aquatic organisms, and aquatic habitats.	• Reference datasets and protocols for restoration strategies for aquatic habitats, fishes, and macroinvertebrates.	• Improved management products for the relocation, reintroduction and restoration of aquatic biological communities.
5B2. Study factors that limit aquatic species and model recovery trajectories to support scientifically valid Habitat Conservation Plans (HCPs).	• Assessment, limiting factor analyses, and risk assessment techniques are available to managers.	• Improved assistance and program management for the restoration of biological populations.
5B3. New: Develop aquatic restoration techniques based on habitat requirements for various life history stages of aquatic species.	• Protocols and standard sampling and analysis techniques for life stage investigations and assessments**.**	• Improved datasets for biological communities for assisting managers develop restoration program products.
Objective 5C: Quantify the ecological and economic effects of natural and human disturbance on aquatic species and aquatic habitats.		
Strategy	**Outcome**	**Measure**
5C1. Identify responses of major biota to restoration efforts in large impounded rivers and lakes using data from long-term research, monitoring and evaluation programs.	• Synthesis of persistent datasets to quantify ecological benefits of restoration activities.	• Assist managers with decisions for optimal benefits of restoration programs.
5C2. Document existing habitat conditions and status of fish populations to recommend prioritized habitat restoration activities to support reintroduced or naturally colonizing populations of imperiled fishes and aquatic organisms.	• Improved long-term data collection and datasets for assessments and predictions of benefits from restoration programs.	• Assist managers with improved information on biological community status to determine restoration goals.

5C3. New: Determine the economic costs and benefits of restoration and reestablishment alternatives.	• Development of criteria for and evaluations of progress and effectiveness of re-establishment and restoration methods. • Synthesis of long-term ecological data with economic data for benefit analysis.	• Tools for managers to prioritize restoration activities for maximum benefit to sustain biological communities.
Goal 6. Research Support and Technical Assistance *Enhance research capabilities to **provide research support and technical assistance** to DOI bureaus, other Federal and State government agencies, Tribes, and non-governmental organizations for application in natural resource management problem solving and decision making.*		
Objective 6A: Provide timely, responsive, cost effective, and scientifically credible products and information in response to critical issue-driven, site-specific management problems involving targeted, short-term research.		
Strategy	**Outcome**	**Measure**
6A1. Provide rapid response to investigate acute water quality, disease, and contaminant exposure episodes and their effects on fish or other aquatic organisms.	• Application of USGS multidisciplinary capabilities to rapid response requests in acute situations.	• Timely dissemination of information on water quality, disease, and contaminant thresholds and effects to managers.
6A2. Anticipate and respond to requests for research to provide systematic analyses and assessments for emerging science needs.	• Design of long-term monitoring programs using tested and verified protocols and standard operating procedures. • Develop, implement, and participate in interagency research project teams.	• Bureau documents, reports, scientific journal publications and other data and analysis products. • Responses to data inquiries and syntheses of long-term datasets for natural resource managers.
6A2. Provide critical review of management plans, answer scientific questions, and help design natural resource management projects.	• Management plans are reviewed and hypothesis driven research proposals and projects are developed. • Development of funding initiatives.	• Responses to data inquiries and syntheses of long-term datasets for natural resource managers.

Objective 6B: Provide sustained scientific support using the multi-disciplinary expertise and experience of USGS.		
Strategy	**Outcome**	**Measure**
6B1. Provide research support and technical assistance to regional organizations to support effective management of inter jurisdictional fisheries, aquatic habitats, and invasive species.	• Participation on endangered species recovery teams, system review teams, and other technical teams.	• Improved delivery of scientific information for the management of fishes, aquatic organisms, and aquatic habitats.
6B2. Incorporate the expertise of multiple scientific disciplines in research support projects.	• Synthesis of different data types, models, and methods from varied sources for landscape-scaled assessments.	• Assistance to partners and customers in determining natural resource management and policy decisions.
6B3. Provide research support, technical assistance and information transfer to natural resource managers.	• Scientific information is made available to support management and decision making.	• Increase in scientific assessments and information base delivered for management and decision making to sustain biological communities.
Objective 6C: Anticipate research and development needs to address emerging issues by soliciting the relevant and long-term research needs of clients		
Strategy	**Outcome**	**Measure**
6C1. Meet and communicate on a regular basis with natural resource managers to review scientific needs, and determine long-term and predict emerging science needs.	• USGS FAER advisory group formed to develop and maintain strategic directions under thematic goals.	• Increased contacts with resource managers to determine science needs. • Increase in the development of systematic analyses and assessments to assist in the management of biological communities.

BENEFITS TO PARTNERS AND CUSTOMERS

The FAER Program focus is to support DOI management of public lands and waters, and DOI trust species and habitats. The Program collaborates internally with other USGS Programs to provide integrated science capabilities to partners and customers. A diverse group of Federal, State and international agencies, as well as non-governmental organizations and commercial entities request USGS research support and technical assistance to provide a scientific basis for management and decision making for aquatic resources (Appendix C). Collaborations among USGS partners and customers have ensured funding for critical issues related to adaptive management to sustain the health of the Nation's aquatic resources.

SOCIETAL NEEDS

An appreciation for the natural resources of the United States runs deep in the national character in a country that has a tradition of setting aside large tracts of forest and rangeland, and establishing parks, national monuments, and scenic waterways to manage and preserve unique landscapes. Aquatic habitats, fishes and other aquatics organisms are an integral part of these larger ecosystems, and the integrity of aquatic habitats and aquatic species is tied closely to management of these resources. The role of the FAER Program is to provide the scientific information necessary to manage our aquatic resources for the future. The protection of these resources provides social, economic and cultural benefits for current and future generations.

IMPLEMENTATION

The new goals, objectives and strategies will be implemented by FAER scientists who are being directed to incorporate new approaches into ongoing and future systematic analyses, assessments and evaluations. Program direction is provided annually to the Regions and Research Centers through the Annual Program Guidance for Biological Research and Monitoring Programs. FAER Program activities are also reviewed on an annual basis during project reviews to ensure that activities are progressing or are completed according to project timelines. Science planning and implementation activities at the regional and science center levels are to address specific science needs. FAER scientists were instrumental in surveying the many partners, customers, and collaborators who provided information on current and future science needs, and in developing the interdisciplinary strategies that incorporate capabilities from other USGS programs. The new scientific insights that will be gained from this interdisciplinary research will support multi-species and landscape-scaled management. This is especially important in the management of aquatic species with large geographic ranges, and large aquatic systems.

ACKNOWLEDGMENTS

We acknowledge the efforts, professional dedication and expertise of the members of the Fisheries: Aquatic and Endangered Species Advisory Committee and writing teams. Their close research associations with USGS partners and customers have resulted in a responsive strategic plan that describes ongoing, planned, and new directions for the Fisheries: Aquatic and Endangered Resources Program. Special thanks to Carolyn Bell, USGS Communications Officer, who served as facilitator for the initial Strategic Planning Meeting, and served to bring a valued Bureau perspective to the scientists.

Douglas Beard, Fisheries and Aquatic Resources Node, National Biological Information Infrastructure
Kenneth Bovee, Fort Collins Science Center
Nina Burkhardt, Fort Collins Science Center
Jeanette Carpenter, Fort Collins Science Center
Mary Freeman, Patuxent Wildlife Research Center
William Gingerich, Upper Midwest Environmental Science Center
Dale Honeyfield, Leetown Science Center
Howard Jelks, Florida Integrated Science Center
Barry Johnson, Upper Midwest Environmental Science Center
Benjamin Letcher, Leetown Science Center
William Loftus, Florida Integrated Science Center
Chuck Madenjian, Great Lakes Science Center
Joseph Margraf, Alaska Cooperative Research Unit
Steve McCormick, Leetown Science Center
Matthew Mesa, Western Fisheries Research Center
Cheryl Morrison, Leetown Science Center
Jennifer Nielsen, Alaska Science Center
Frank Panek, Leetown Science Center
Diana Papoulias, Columbia Environmental Research Center
Edward Pendleton, Leetown Science Center
James Petty, Central Region
Gary Scoppetone, Western Fisheries Research Center
Rip Shively, Western Fisheries Research Center
Lyman Thorsteinson, Western Fisheries Research Center
Thomas Todd, Great Lakes Science Center
Mark Wildhaber, Columbia Environmental Research Center
James Winton, Western Fisheries Research Center
Carol Ann Woody, Alaska Science Center
Christopher Zimmerman, Alaska Science Center

Many thanks to USGS reviewers from other Programs and Disciplines.

Bobbie Bauldock, Bioinformatics Program
Rebecca Cole, National Wildlife Health Center
Kenneth Dodd, Florida Integrated Science Center
David Greene, Biological Resources Discipline
Thomas Gunther, Geographic Information Office
Martin Gurtz, Water Resources Discipline
Steven Gutreuter, Upper Midwest Environmental Science Center
David Hamilton, Fort Collins Science Center
Richard Jachowski, Northern Rocky Mountain Science Center
Susan Jones, Columbia Environmental Research Center
George Kish, Florida Integrated Science Center
Cynthia Kolar, Upper Midwest Environmental Science Center
Kevin Lafferty, Western Ecological Science Center
Lynn Lefebvre, Florida Integrated Science Center
Robert Milhous, Water Resources Discipline
William Richardson, Upper Midwest Environmental Science Center
Christian Torgersen, Forest and Rangeland Ecosystem Science Center
William Smith Vaniz, Florida Integrated Science Center

We offer our sincere thanks to the individuals in our partner and customer natural resource agencies who offered their comments and recommendations.

Gary Jensen, USDA, Cooperative State Research, Education and Extension Service
Thomas Roberts, Bureau of Land Management
Michael Sissenwine NOAA Fisheries
James Tilmant, National Park Service
Tim Toplisek and Michael White, USACOE
Steve Waste, Northwest Power and Conservation Council

The draft strategic plan was also circulated to the:

US Bureau of Reclamation
US Fish and Wildlife Service
US Forest Service
US Department of Energy

American Fisheries Society
International Association of Fish and Wildlife Agencies
Natureserve

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U. S. National Biological Information Infrastructure, Fisheries and Aquatic Resources Node. Available online at: **http://far.nbii.gov/**

APPENDIX A LIST OF ACRONYMS

AFS	American Fisheries Society
ASC	Alaska Science Center
BRD	Biological Resources Discipline
BLM	Bureau of Land Management
CAFL	Conte Anadromous Fish Laboratory
CBFWA	Columbia Basin Fish and Wildlife Authority
CERC	Columbia Environmental Research Center
CVM	Center for Veterinary Medicine
DOI	Department of the Interior
EMS	early mortality syndrome
FAER	Fisheries: Aquatic and Endangered Resources Program
FISC	Florida Integrated Science Center
FORT	Fort Collins Science Center
GIS	Geographic Informational System
GLSC	Great Lakes Science Center
HCP	Habitat Conservation Plan
IPNV	infectious pancreatic necrosis virus
ISAV	infectious salmon anemia
LSC	Leetown Science Center
NBII	National Biological Information Infrastructure
NBS	National Biological Survey
NGO	Non-Governmental Organization
UMESC	Upper Midwest Environmental Science Center
USACOE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFC	United States Commission of Fish and Fisheries
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UW	University of Washington
WFRC	Western Fisheries Research Laboratory

APPENDIX B CONGRESSIONAL AUTHORIZATIONS

The US Geological Survey has the primary responsibility to provide high-quality scientific data to the Department of the Interior and its Bureaus. The USGS operates under many Congressional authorizations (see USGS CONGRESSIONAL AUTHORIZATIONS http://water.usgs.gov/usgs/congress/appendE.html**)** that set forth a role for USGS aquatic resources research.

16 U.S.C. 1-4, 17j-2, 18f, 431-433, 461-467 *National Park Service Organic Act, as amended and supplemented.*

16 U.S.C. 661 et seq. *Fish and Wildlife Coordination Act of March 10, 1934, (P. L. 79-732) authorizes the Secretary of the Interior to prepare plans to protect wildlife resources, to conduct surveys on public lands, and to accept funds or lands for related purposes; authorizes the investigation and reporting of proposed Federal actions that affect the development, protection, rearing, and stocking of all species of wildlife and their habitat in controlling losses, minimizing damages, and providing recommendations to minimize impacts on fish and wildlife resources.*

16 U.S.C. 742(a)742d, 742e-742j-2 *Fish and Wildlife Act of 1956 authorizes the Secretary of the Interior to conduct investigations, prepare and disseminate information, and make periodic reports to the public regarding the availability and abundance and the biological requirements of fish and wildlife resources; provides a comprehensive national fish and wildlife policy and authorizes the Secretary of the Interior to take steps required for the development, management, advancement, conservation, and protection of fisheries and wildlife resources through research, acquisition of refuge lands, development of existing facilities, and other means.*

!!!!!16 U.S.C. 753a *The Fish and Wildlife Improvement Act of 1978 as amended by P.L. 95-616, authorizes the Secretary of!!!!! the Interior to enter into cooperative agreements with colleges and universities, State fish and game agencies, and nonprofit organizations for the purpose of developing adequate, coordinated, cooperative research and training programs for fish and wildlife resources.*

16 U.S.C. 931939 *Great Lakes Fishery Act of 1956 implements the Convention on Great Lakes Fisheries between the United States and Canada; authorizes construction, operation and maintenance of sea lamprey control works; and established the Great Lakes Fisheries Commission.*

16 U.S.C. 13611362, 13721384, 14011407 *Marine Mammal Protection Act of 1972, as amended (establishes a responsibility to conserve marine mammals with management authority vested in the Department of the Interior for the sea otter, walrus, polar bear, dugong, and manatee.*

16 U.S.C. 15311543 *Endangered Species Act of 1973, as amended provides for the conservation of threatened and endangered species of fish, wildlife, and plants; and*

authorizes establishment of cooperative agreements and grants-in-aid to States that establish and maintain active and adequate programs for endangered and threatened wildlife and plants.

16 U.S.C. 28012810 *National Aquaculture Act of 1980 directs the Secretary of the Interior to participate in the development of a National Aquaculture Development Plan and authorizes research, development, and other activities to encourage the development of aquaculture in the United States.*

16 U.S.C. 3141 et seq. *As a result of the Alaska National Interest Lands Conservation Act (1980), the Geological Survey has made and may be called upon to make water studies pertinent to implementation of the act.*

30 U.S.C. 1201 et seq. *Surface Mining Control and Reclamation Act of 1977, as amended, established the Office of Surface Mining Reclamation and Enforcement (OSM). OSM depends in part upon the Geological Survey for a determination of the probable*

31 U.S.C. 6301 et seq. *Federal Grant and Cooperative Agreement Act of 1977 provides criteria for distinguishing between contract, grant and cooperative agreement relationships and provides discretionary authority to vest title to equipment or other tangible personal property purchased with contract, grant or cooperative agreement*

33 U.S.C. 1251 et seq. *Federal Water Pollution Control Act Amendments of 1972 and its successors, the Clean Water Act of 1977 and the Water Quality Act of 1987, authorize extensive water quality planning, studies, and monitoring under the direction primarily of the Environmental Protection Agency (EPA). The Geological Survey is called upon to participate in many of these activities, partly by EPA and partly by State agencies in the Federal-State Cooperative Program. The act of 1987 includes new water quality work concerning Chesapeake Bay, the Great Lakes, Estuary and Clean Lakes Programs, and studies of water pollution problems in aquifers.*

33 U.S.C. 2201 et seq. *Water Resources Development Act of 1990, authorizes a program for planning, construction, and evaluation of measures for fish and wildlife habitat rehabilitation and enhancement; cooperative effort and mutual assistance for use, protection, growth, and development of the Upper Mississippi River system; implementation of a long-term resource monitoring program; and implementation of a computerized inventory and analysis systems.*

42 U.S.C. 4321 et seq. *The National Environmental Policy Act of 1969 requires the Geological Survey to comply with Section 102(2)(C) which pertains to review of Environmental Impact Statements (EIS's) prepared by other agencies. The Geological Survey reviews EIS's for nuclear power plant sites and other critical facilities.*

42 U.S.C. 4331 et seq. *National Environmental Policy Act of 1969 (NEPA), requires prior to action determination that any major Federal action will not have a significantly*

adverse effect upon the environment. Consequently, the Geological Survey is called upon to provide technical review or inputs to resource related actions proposed by other

42 U.S.C. 8901 et seq. *Acid Precipitation Act of 1980 (Title VII of the Energy Security Act) calls for an "Acid Precipitation Program and Carbon Dioxide Study." The Geological Survey is an active participant in studies of acid precipitation as a result of prior work in this field in the Federal and Federal-State Cooperative Programs.*

42 U.S.C. 10301, note Section 1121*, the Water Resources Development Act of 1986 (P.L. 99662), amends the Water Resources Research Act of 1984 by adding, as title III, "Ogallala Aquifer Research and Development." P.L. 101397 reauthorizes the Water Resources Research Act through 1994.*

43 U.S.C. 31 et seq. *The Organic Act of March 3, 1879, that established the Geological Survey, as amended (1962); and restated in annual appropriation acts. This section provides, among others, that the Geological Survey is directed to classify the public lands and examine the geological structure, mineral resources, and products within and outside the national domain. This section also establishes the Office of the Director of the Geological Survey, under the Interior Department. The Director is appointed by the President by and with the advice and consent of the Senate. P.L. 102285 Sec. 10(a)*

43 U.S.C. 1301 *The Marine Protection, Research, and Sanctuaries Act of 1972 provides that the Secretary of Commerce must consult with the Secretary of Interior prior to designating marine sanctuaries. The USGS provides information regarding the energy and mineral resource potential in areas being considered for designation as marine sanctuaries.*

43 U.S.C. 1701 et seq.; 43 U.S.C. 1737 *The Federal Land Policy and Management Act of 1976 (FLPMA) and the Studies, Cooperative Agreements, and Contributions Implementation Provisions, authorize the Secretary of the Interior to conduct investigations, studies, and experiments involving the management, protection, development, acquisition, and conveying of public lands; and to prepare and maintain inventories of all public land and resources.*

46 U.S.C. 31(a) and (b) *The Coastal Zone Management Act of 1976 provide that each department, agency, and instrumentality of the Executive Branch of the Federal Government may assist the Secretary (of Commerce), on a reimbursable basis or otherwise, in carrying out research and technical assistance for coastal zone management.*

P.L. 101397 *Water Resources Research Act reauthorization through 1995 provides for water resources research, information transfer, and student training in grants and contract programs that will assist the Nation and the States in augmenting their science and technology to discover practical solutions to water shortage and quality deterioration problems.*

P.L. 101606 *The Global Change Research Act of 1990 established the United States Global Change Research Program aimed at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment, to promote discussions toward international protocols in global change research, and for other purposes.*

P. L. 101646 *Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, establishes a Federal program to prevent introduction of and to control the spread of introduced aquatic nuisance species and the brown tree snake.*

P.L. 102580 *Water Resources Development Act of 1992 establishes a National Contaminated Sediment Task Force, with USGS as a Member, to conduct a comprehensive national survey of aquatic sediment quality.*

49 Stat. 1894 *Outdoor Recreation Act of June 23, 1936 authorizes the Secretary of the Interior to sponsor, engage in, and assist in research relating to outdoor recreation, directly or by contract or cooperative agreements, and make payments for such purposes; undertake studies and assemble information concerning outdoor recreation; and cooperate with educational institutions and others in order to assist in establishing education programs and activities and to encourage public use and benefits from outdoor recreation.*

APPENDIX C PARTNERS, CUSTOMERS, AND COOPERATORS

Many Federal, State and Provincial, Tribal and First Nation, Alaska Native, non-governmental, commercial and local groups collaborate with USGS scientists to develop and implement research and technical assistance projects to answer critical information needs for natural resource managers, user groups, and decision makers. The following list in not all inclusive, but represents major partners during the time the plan was under development.

Department of Interior Bureaus:

Fish and Wildlife Service
National Park Service
Bureau of Land Management
Bureau of Reclamation
Bureau of Indian Affairs
Minerals Management Service
Office of Surface Mining

Other Federal Agencies:

Food and Drug Administration - CVM
Department of Defense
Department of Agriculture – Forest Service
Department of Commerce - NOAA
Army Corps of Engineers
Environmental Protection Agency
Department of Energy
Center for Disease Control
Department of Health and Human Services

States:

All 50 States and US Territories

Examples of Tribal Partners:

Confederated Tribes of the Umatilla
Confederated Tribes and Bands of the Yakima Nation

Examples of non-governmental, regional and local organizations (NGOs):

Great Lakes Fishery Commission
International Assoc. of Fish and Wildlife Agencies
Columbia Basin Fish and Wildlife Authority
City of Chicago
Interagency Committee for Lower Columbia Fish Enhancement
Numerous Colleges and Universities