5-Year Plan for the

USGS Contaminant Biology Program

2005-2010

1/12/05

PREFACE

Formulation of the 5-Year Plan

This plan was produced using a widely inclusive process involving the USGS research community and numerous partner agencies. Using partner input and recommendations from the Program Review conducted in 2002, the Contaminant Biology Program (CBP) Coordinator divided the program into eight areas of emphasis. These topics encompassed the range of current and projected research activities, and the areas of special interest to our major partners. The topics were: endocrine disruption, mercury, contaminated habitats/NRDA/irrigation drainwater, metals and mine waste, toxicity testing/criteria development, multi stressors/species, chemistry and toxicity of emerging contaminants/new generation pesticides, and monitoring and biomarkers, sampling devices, molecular biology. Then, from Regional and Center nominations, the Program Coordinator formed a Planning Team of eight senior-level scientists, the Program Coordinator for the Toxic Substances Hydrology Program and herself. Each of the eight scientists assumed lead responsibilities for one of the topics, for which they had extensive research experience. Each scientist organized and hosted a consistently formatted two-hour conference call for their topic. The conference call provided an overview of the process, a summary of relevant BRD science activities, and presentations by invited partners. With input from the calls, the Budget and Science Information System, and summaries of research provided by CBP scientists, planning team scientists developed a white paper for the Strategic Plan for their topic. Recommendations from these eight documents became the objectives and strategies of the final 5-Year CBP Plan. This entire process involved several organizational conference calls, the eight topical conference calls, one face-to-face meeting of the Planning Team and plan preparation by the Program Coordinator. The plan was reviewed by the planning team, the call participants and USGS personnel, and official review by partner agencies.

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EXECUTIVE SUMMARY

Mission

> The Mission of the Contaminant Biology Program (CBP) is to provide high quality, objective scientific information on exposure and effects of environmental contaminants to biotic resources for management, protection and restoration the Nation's biotic resources and in particular, the trust resources of the Department of the Interior (DOI).

To achieve this outcome, the CBP conducts research, collects data and disseminates information on environmental toxicology and chemistry to biologists, resource managers and regulators of environmental contaminants from DOI and other agencies. Contaminant Biology expertise, research, scientific interpretations, monitoring tools, and models are primary sources of information for preventing contamination, restoring contaminated DOI lands and trust resources, fulfilling recreational, statutory and regulatory responsibilities. The information improves the understanding of the environmental effects of current and emerging contaminants.

Goals and Objectives

The 5-Year plan lays out a framework of goals and objectives and a strategy to reach those objectives.

Goal 1. Toxicology and Chemistry

Develop methods and generate information to determine sources, fate, exposure and effects of environmental contaminants. Develop and standardize biomarkers, molecular biology methods and other analytical and toxicological assays.

> Objective 1A. Identify and quantify contaminants in water, sediments, and biota and other environmental media through the development and application of validated analytical methods and techniques.
>
> Objective 1B. Develop, validate and standardize molecular, biochemical and physiological methods to determine toxicity or exposure in species of concern or their surrogates.
>
> Objective 1C. Determine mechanisms of action and toxic effects of priority contaminants on organisms, populations and communities.
>
> Objective 1D. Determine the relative sensitivity of different species and life stages to contaminants.

Goal 2. Contaminated Habitats

Develop the scientific basis for assessment, restoration and monitoring of habitats that are contaminated by mining, agriculture, urban wastewater, industry, and chemical control agents. Develop toxicological criteria to remediate or prevent contamination effects.

Objective 2A. Provide scientific information for Natural Resource Damage Assessment and Restoration (NRDAR) of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites and assessment, remediation and restoration of other contaminated sites. Determine the risk of environmental contaminants to fish and wildlife resources on DOI lands.

Objective 2B. Investigate the effects on nontarget terrestrial and aquatic fauna of agricultural, rangeland and forestry chemicals.

Objective 2C. Quantify ecological changes caused by contamination associated with energy development and use, and develop new tools for designing and evaluating remediation.

Objective 2D. Evaluate ecological impairment caused by mercury in susceptible aquatic and terrestrial habitats.

Objective 2E. Evaluate ecological effects associated with urban and industrial development.

Objective 2F. Characterize exposure, bioavailability and ecological effects of metals, minerals and chemicals associated with mining (e.g., cyanide) at contaminated sites.

Goal 3. Integration of Ecological Stressors

Improve the scientific basis for evaluating the effects of multiple stressors at all levels of biological organization and at multiple temporal or spatial scales.

Objective 3A. Develop models, databases and other tools for predicting environmental exposure to, and effects of contaminants and ecosystem recovery.

Objective 3B. Examine ecological and toxicological effects of chemical and nonchemical stressors in organisms, populations of species of concern, and communities. Establish links to specific biomarkers.

5- YEAR PLAN FOR THE CONTAMINANT BIOLOGY PROGRAM

Mission

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The CBP sustains the mission of DOI by providing DOI managers with scientific information to meet the challenges of its Resource Protection Goal to "improve health of watersheds, and landscapes" relative to environmental contaminants. It also contributes to other DOI goals, such as sustaining biological communities, and its recreational goal. Likewise, the CBP contributes to the mission of the U.S. Geological Survey (USGS) to "provide the Nation with reliable, unbiased 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" by supplying information on the effects of contaminants on biological resources. Other Federal, State and local agencies also use CBP information in decision-making to improve the health of ecosystems.

Expected Outcomes and Outcome Measures

The ultimate goal and desired outcome of the activities and contributions of the CBP is improving the health of watersheds and landscapes for DOI trust lands and resources and ultimately the Nation as a whole. The CBP helps DOI to achieve this goal through the provision of scientific information. The products and outcomes of the CBP contribute materially to our quality of life and to our understanding of the global environment, and provide an information base for regulatory decisions that ultimately prevent contaminants from becoming problems. The intermediate outcomes of Program outputs are the advancement of knowledge for decision making and improvement of techniques for contaminant assessment and monitoring. To achieve these intermediate outcomes, the CBP conducts research and communicates information from research and data collection to decision makers, resource managers and regulators of environmental contaminants. The program develops innovative sampling techniques and strategies, analytical and biomarker techniques and predictive models, and assists in establishing recovery criteria, cleanup levels, restoration goals and risk assessments. Program output measures are the number of internal reports, scientific publications, synoptic reviews, presentations, training sessions, workshops, technical assistance meetings, thematic maps, databases, websites, models and other scientific products.

The complexity of these outcomes requires a multifaceted approach to document the utility of the scientific products. Measures include:

- Documented use of BRD findings by agencies and Bureaus in regulation, policy, restoration and other resource management decisions. (Number of sites or species where USGS scientific information was used to assess, mitigate or restore a species or environment,
- Number of Citations referenced in the Science Citation Index or Federal Register,
- Provision of funds for research projects from resource management and regulatory agencies and Bureaus,
- Improvements in the efficiency, reliability, and accuracy of contaminant monitoring, and
- Evidence that private citizens and nongovernmental organizations find the information useful.

Why does the Nation need the USGS Contaminant Biology Program?

Preserving our quality of life requires a dynamic balance, ensuring that our economy is strong while protecting human and environmental health. Scientific information enables the policy makers and resource managers to make informed choices and avoid negative consequences caused by contamination of lands and waters. The CBP plays a vital role in informing decision makers about the effects of environmental contaminants on the health and viability of DOI trust resources. Contaminant Biology research, monitoring tools, and models establish a scientific foundation to remediate and restore hazardous waste sites on or affecting DOI land and trust resources. Cleanup and restoration of contaminated sites require high quality, objective scientific information and development of criteria to determine the extent of cleanup and the goals and success of restoration efforts in order to meet the DOI's conservation goals.

Unremediated hazardous waste sites are of particular concern to DOI and other land management agencies. DOI is responsible for NRDAR under CERCLA and other legislation for hundreds of thousands of abandoned minelands and waste sites within our National Parks, Refuges and Rangeland. The Fish and Wildlife Service (FWS) and the Bureau of Land Management (BLM) use USGS data to fulfill its regulatory and oversight responsibilities under the Clean Water Act, CERCLA, the Endangered Species Act, the Migratory Bird Treaty Act and other statutes and in many cases, to take proactive measures to avoid, reduce or mitigate contaminant problems. Resource managers in FWS, BLM, National Park Service (NPS), Bureau of Reclamation, and

Office of Surface Mining and other Federal, State, and local agencies also use information generated by USGS to determine the role of contaminants in species declines or die-offs. USGS is investigating contamination on NPS land (including Golden Gate, Lake Mead and Whiskeytown-Shasta-Trinity National Recreation Areas (NRA), Acadia, Grand Teton, and Big Bend National Parks (NP), Rock Creek Park, and Ozark National Scenic Riverways); FWS National Wildlife Refuges (NWR) (including Agassiz, Lostwood, Great Bay, Kenai, Prime Hook, Blackwater, Carson Lake and Stillwater NWR); and BLM land associated with Clark Fork, Bear Creek, Yuba River, Deer Creek, Trinity River, Coeur d'Alene, and Clear Creek. Many State agencies rank water quality and pollutants among their top issues[i]. USGS is one of few Federal agencies that provide scientific information on environmental toxicology and chemistry related to fish and wildlife.

Other Federal agencies, such as the Environmental Protection Agency (EPA), use USGS information for regulation, remediation, and restoration. CBP research improves the information base and tools for monitoring, evaluation and restoration decisions and in setting regulations for toxic substances. Many of the most contaminated habitats are CERCLA sites, which are overseen by EPA and the States. In addressing environmental health, the EPA emphasizes human health and tool development for regulation rather than for land and resource management. The National Oceanic and Atmospheric Administration (NOAA) and DOI share concerns about contaminated habitats, but NOAA emphasizes in marine and coastal environments, whereas the CBP emphasizes terrestrial and freshwater environments. USGS supports the Department of Defense (DOD) on military installations that have a variety of contaminant concerns including explosives, metals, solvents, and fuels. The CBP conducts research on and off of DOI lands because of DOI's trust responsibilities for migratory birds, anadromous fish, and other faunal groups.

Although regulation and cleanup activities have been effective at reducing the effects of contaminants in the environment, the problems are far from solved. For approximately 80% of threatened and endangered species, pollution or contamination are significant limiting factors contributing to population declines[ii]. The sensitivity to contaminants of many of these species is not well understood because they are in taxonomic groups for which little testing has been done and few methods have been developed. Instances of die-offs, deformities and declining populations of fish and wildlife are still found nationwide. Continuing conversion of habitat to other uses increases the urgency of restoring and conserving the remaining habitat. Atmospheric circulation redistributes some contaminants throughout the world, so heavily contaminated areas serve as sources less contaminated areas. Nowhere is this more apparent than in parts of the arctic where local contaminant sources are minimal, yet concentrations of mercury and persistent organic contaminants affect the health of DOI trust species and people who subsist on many of those species.

Biological resources are exposed to an increasing number of newly introduced pesticides, personal care products, and industrial chemicals whose effects on the environment are not well understood. As technological advances make their way into production, understanding their potential effects becomes more urgent. Organisms that are genetically engineered to produce and deliver pesticides and that are released into the environment, make them, in essence, pesticides or drugs that can reproduce, hybridize and exhibit other behaviors typical of the species. The physiological effects and potential toxicity of nanoparticles that are engineered as microtubules and other physiologically active entities are just beginning to surface.

Although other Federal and State agencies, universities and private companies conduct research on environmental contaminants, the research of the USGS CBP is unique in the combination of qualities that characterize it. CBP is characterized by the long-term, uninterrupted duration of its research. Research areas are chosen because of serious potential risks to trust resources. The work of CBP biologists, while on the cutting edge scientifically, is dedicated to solving practical contaminant problems with long-term solutions. The CBP is staffed by an array of environmental toxicologists, chemists and modelers that is unmatched by any other organization. CBP research provides an early warning system that can alert the Nation about incipient contaminant threats to species and ecosystems.

Program History

Wildlife and aquatic environmental contaminant research developed independently in the 1940s and late 1950s, respectively. Increased use of pesticides and industrial chemicals following World War II led to wildlife contaminant research at the Patuxent Wildlife Research Center (Patuxent) in Maryland, and aquatic toxicology work at the Denver Wildlife Research Center of the FWS. Over the course of 60 years of research on the effects of contaminants on wildlife, Patuxent scientists have conducted research on such diverse pollutants as organochlorine and organophosphate pesticides, oil, polychlorinated biphenyls (PCBs), dioxins, white phosphorus, lead, cyanide, selenium, arsenic, acid precipitation, and herbicides. Recent science at Patuxent has examined comparative avian sensitivity to mercury, amphibian sensitivity to pesticides, endocrine disruption, risk assessment, effects of new pesticides, effects of methylmercury and vanadium on birds and field studies at several contaminated sites.

Aquatic toxicology activities at the FWS Denver Wildlife Research Center (Denver) moved to Columbia, Missouri in 1966. The Columbia Environmental Research Center (Columbia) originally focused on the toxicity of pesticides to fish and invertebrates, pesticide analytical methods, and effects of pesticides on fish and fish habitat. In the 1970's and 1980's the Center's activities expanded to include the National Pesticide Monitoring Program and research on acid precipitation, irrigation drainwater, contaminated sediments, oil development and mining in Alaska, fish tumors, regional contaminant investigations, and environmental chemistry. More recently, Columbia has studied contaminant exposure and effects, risk assessment, sediment exposure and toxicity, bioassessment tools and technologies, and biomarker development. Scientists at both Patuxent and Columbia have primarily conducted controlled laboratory studies and some fieldwork, with additional fieldwork performed through the field stations associated with each of the laboratories.

In 1993, Secretary Babbitt moved many research biologists from DOI bureaus into his newly forged National Biological Survey (NBS). In 1996, NBS was moved into USGS and renamed the Biological Resources Division (BRD). In 1997, many contaminants research field stations were reassigned to other Centers in their region, diversifying the focus of these Centers to include a contaminant biology element. This organizational change increased the challenge of integrating field and laboratory studies -- an essential element in presenting the multiple lines of evidence needed to demonstrate the effects of contaminants in the field, and of maintaining a critical mass of contaminant scientists and facilities at the smaller units. Nonetheless, the smaller units have accumulated an impressive array of findings on their own. Studies of contaminated sites, endocrine disruption, development of biomonitoring tools such as swallows, issues, demethylation of mercury in raptors, effects of PCBs and mercury, immunotoxicology and fish tumors are just a few of the scientific areas where these scientists are engaged. CBP scientists from FWS and NPS continue to maintain close personal and professional ties with personnel in their former agencies. Those ties facilitate communication of specific bureau scientific needs to CBP scientists. Other agencies and Bureaus also provide much-needed logistical and financial support. The CBP depends on this interaction to maintain the vitality of its research program.

Accomplishments

Historical Accomplishments

Research in the CBP continues a long tradition of fundamental discoveries about ecological effects of environmental contaminants on wildlife. One of the earliest accomplishments linked wildlife die-offs and population declines to DDT and other persistent organochlorine pesticides. In the 1960s Patuxent and Denver scientists demonstrated that DDE, a metabolite of DDT, caused eggshell thinning in many birds, leading to reproductive failure. By the late 1960s, toxicologists also demonstrated the effects of PCBs on fish and wildlife. Research at Patuxent and the National Wildlife Health Laboratory in Madison, Wisconsin (Madison) on the toxicity of lead shotgun pellets influenced decisions to ban the use of lead shot for waterfowl hunting in the 1970s. Research on other metals in the 1970s and 1980s led to the regulation of mercury. Research on the acute and chronic effects of crude and refined petroleum during the late 1970s helped determine the design of regional oil spill response plans and contributed to the development of guidelines for use of chemical dispersants in oil spill response. In the 1980s and 1990s, CBP scientists documented toxic effects of selenium on birds and other biota at the Kesterson National Wildlife Refuge and studied many other sites in the western U.S. that received irrigation drainwater. Research on biomarkers of contaminants began in the 1970s and continues today. In the 1990s, laboratory and field studies identified the widespread hazards of cyanide used in gold mining. Scientists from multiple Centers documented that waterfowl and fish were killed by lead when feeding in sediments that had been contaminated with mine tailings.

The CBP has also provided a wide array of aquatic dose/response and environmental fate data for a broad spectrum of agricultural and industrial contaminants to establish effects thresholds and to define food chain effects. Much of the aquatic work has been done at Columbia. State and Federal monitoring programs have adopted CBP analytical and field methods. Toxicological and environmental chemistry information is widely used by FWS, EPA, NOAA and other organizations for resource management and regulatory decisions. CBP scientists have developed a series of artificial sampling devices that are used worldwide to estimate aquatic animal exposure to several types of chemicals in aquatic environments. Many present-day monitoring programs depend on the data generated by the National Contaminant Biomonitoring Program, which was conducted by FWS scientists. Many of these scientists are now part of the CBP.

Recent Accomplishments - Toxicology and Chemistry

Sediment quality guidelines
USGS, in cooperation with other agencies, has developed consensus-based numerical Sediment Quality Guidelines (Guidelines) for 28 chemicals in freshwater ecosystems, including metals, industrial chemicals, and pesticides. USGS used a North American national freshwater sediment database with matching chemistry and sediment toxicity data to develop models to predict toxicity and establish Guidelines. These Guidelines are currently being used to assess the quality of sediments at many locations across North America, in combination with toxicity tests, measures of bioaccumulation, and benthic community evaluations. The FWS applied the Guidelines in a recent NRDAR injury assessment of Indiana Harbor (Southern Lake Michigan), and won a $75 million settlement for restoration of the site.

Development of toxicity methods for mussels
More than 70% of North America native freshwater mussel species (Unionidae), are endangered, threatened, or of special concern[iii]. Of the factors that contribute to the decline of mussel populations, water pollution has been one of the most difficult to investigate because of the lack of bioassay techniques for this group of animals. The larval stage (the glochidium) of freshwater mussels is parasitic on fish, and the larval, juvenile and adult stages present special challenges in toxicity testing. USGS scientists worked with FWS, EPA and Southwest Missouri State University to develop methods and determine the contribution of degraded water quality to the decline in freshwater mussels. Scientists refined and standardized toxicity test methods with different life stages of freshwater mussels and used these methods to evaluate the toxicity of ammonia, chlorine, and copper. Results indicated that EPA water-quality criteria based on data generated with surrogate species such as daphnids, fathead minnows, and trout may not protect sensitive life stages of freshwater mussels from copper and ammonia. This project exemplifies the information that the CBP provides the FWS to support its Clean Water Act activities, and is responsive to the recommendations of the CBP Review.

Flame retardants in the environment
Large quantities of polybrominated diphenylether (PBDE) flame retardants are used in polymers (which are 10-30% PBDEs by weight) for household and industrial products as polyurethane foams, electronics, high impact polystyrene, carpet and seat cushions. These PBDEs are a family of compounds, somewhat like PCBs, that readily enter the environment. Certain PBDEs disrupt thyroid hormones and alter behavior. CBP scientists, working with FWS, are investigating PBDE chemistry and presence in fish and wildlife. When Sweden researchers showed that PBDE levels in human breast milk were doubling two to five years, USGS researchers found similar increases in PBDEs in fish and eggs of birds from across the country. USGS researchers have shown that several of the larger PBDEs can degrade into smaller PBDEs that are more readily assimilated by animals and more effective mimics of thyroid hormones than the parent compounds, and are thus more toxic. Concentrations of PBDEs have increased so rapidly that scientists in USGS and FWS are concerned that concentrations may soon exceed toxic thresholds for birds in particular locations. Researchers have identified hotspots so that FWS can focus its efforts where risk is greatest.

Evaluation of chemically induced endocrine disruption in fish
In its continuing investigation of the affects of endocrine disrupting compounds on reproductive performance of fish and wildlife, CBP scientists developed a fish variety whose color indicates its sex, so that scientists can determine sex without dissection. This unique ability allows the study of early effects of chemicals on sex determination and sex-reversal. This fish model can be used to characterize the biochemical, cellular, physiological, and behavioral effects in fish exposed to sex steroids and anti-steroids and to screen chemicals (e.g., atrazine) and environmental mixtures (e.g., effluents from pulp and paper mills) for endocrine disruption.

Recent Accomplishments – Contaminated Habitats

Fish tumors from contaminants in Lake Erie sediment
In the 1980s, CBP scientists demonstrated that polycyclic aromatic hydrocarbons (PAHs) caused liver tumors in fish populations from certain industrialized areas in Lake Erie. Based on this information, the International Joint Commission (IJC) used fish tumors as one of the Beneficial Use Impairments for designation of the 43 Great Lakes Areas of Concern (AOCs). Since the mid 1990's, significant efforts have been made to clean up several of the AOCs on Lake Erie, including dredging contaminated sediments, diversion of industrial effluents, shoreline cleanup, and the natural process of sedimentation. Between 1998 and 2003, a CBP research investigation of Lake Erie re-examined eleven Lake Erie tributaries including nine AOCs. Fish cancer prevalence was reduced and diversity increased at locations where point sources were eliminated and where remedial actions were taken. Information from this research has already been used by the IJC to re-designate two AOCs (Presque Isle Bay, PA and the Black River, OH) as Areas of Recovery. Other AOCs (such as the Detroit River) are using the information to plan further research and remediation for their own re-designation efforts.

Coeur d'Alene mining district

The Coeur d'Alene river drainage of northern Idaho is dotted with abandoned and active lead, zinc, and silver mines. Contamination of this drainage has killed birds and degraded terrestrial and aquatic habitats for the last 70 years. Lead and zinc contamination of federal lands managed by BLM and US Department of Agriculture (USDA) Forest Service (USFS), FWS trust resources, and tribal lands caused the DOI, USDA and the Coeur d'Alene tribe to conduct a NRDAR in the Coeur d'Alene basin (Basin). In support of DOI litigation, USGS scientists characterized the natural resource injuries in over two-dozen peer-reviewed publications and provided expert testimony in Federal court. Using information they developed on toxicity and consumption of lead in environmental media, USGS biologists developed effect levels for lead exposure in birds and fish. Geologists and hydrologists described concentrations, transport, and transformation of lead and zinc, the two primary contaminants. Taken together, this scientific work elucidates the pathways and processes linking metal sources with effects in fish and wildlife. The new scientific information enabled FWS, BLM and the other resource trustees to assess damages and plan restoration. EPA used the USGS data when developing cleanup levels for the basin. USGS is assisting EPA with monitoring programs to evaluate metal loading and development of cleanup technologies to reduce the bioavailability of zinc and lead. The USGS Mineral Resources Program, Wildlife and Terrestrial Resources, and Toxics Substances Hydrology Program also supported this work.

Effects of mercury on birds

Mercury pollution remains one of this country's most challenging contaminant problems. There are more streams and lakes where high methylmercury burdens in fish have necessitated fish consumption advisories than for all other contaminants combined. Although humans can be advised to limit their consumption of methylmercury-contaminated fish, fish-eating and other aquatic birds cannot, leading to higher exposures to mercury. Research has shown that the embryo is the most sensitive life stage for birds. Methylmercury, a highly toxic chemical form that moves up food chains, is taken up by the birds eating contaminated fish and then deposited into eggs where it can cause deformities and mortality. However, the threshold of developmental toxicity of mercury in embryos of various species of birds is unknown. To provide more reliable information on the relative sensitivity to mercury, USGS scientists have injected mercury into eggs from 17 species; including herons, egrets, gulls, terns, rails, cranes, pelicans, ospreys and cormorants; and ranked the sensitivity of embryos of these species. The research found large species differences in bird embryo sensitivity to mercury exposure. Eggs were collected in cooperation with other USGS scientists, EPA staff, and federal and state biologists. This information has helped biologists and resource managers in USGS and other agencies assess the risk mercury in bird eggs across the country.

USGS/EPA Mercury Roundtable

In June 2000, the USGS and the EPA established a USGS/EPA Mercury Roundtable to provide a forum for Federal, State and local governmental personnel to discuss science and its role in affecting policy related to mercury. The Mercury Roundtable was needed because of the scientific and regulatory complexity of mercury issues and the hazards posed by mercury. The Mercury Roundtable facilitates interactions among scientists, managers and policy makers by highlighting key individuals active in specific topical areas of mercury research or policy. Over 400 people from over 100 federal, state, local, tribal, or intergovernmental agencies have participated in one or more of the 18 sessions held between 2000 and 2004.

Recent Accomplishments - Integration of Ecological Stressors

Unintended effects of fire-retardant chemicals

Each year, millions of liters of fire-retardant chemicals are applied during fire season, as the nation combats unwanted wildfires. Some fire retardants may have toxic effects in aquatic habitats that can compound the damage of the fire itself. To determine potential risk of these toxic effects, CBP scientists studied the toxicity and persistence of fire-retardant chemicals and the behavior of organisms that are exposed to them. USGS found that solar ultraviolet radiation significantly increases the toxicity of fire-retardants containing a cyanide compound, YPS (sodium ferrocyanide). Where concentrations of cyanide are high enough to be toxic, fish can escape injury by avoiding fire-retardant chemicals in streams if an uncontaminated avenue of escape is available. Fire destroys the toxicity of the retardant, but unburned areas treated with fire retardant can be a persistent source of toxicity to nearby streams, particularly if rainwater drains sandy or rocky substrates. Other products of fire, such as ash and high temperatures, are also hazardous to aquatic life. Fire retardants are of low toxicity to terrestrial wildlife. This research provides guidance for the selection and use of fire-retardant chemicals by the DOI, USFS and fire managers in other agencies.

Quality and Performance

The CBP continues to improve the quality and performance of its research efforts through reviews at the proposal, publication and program levels. An external panel reviews the CBP on a five-year cycle, with the next review slated for 2007. The review in 2002 made recommendations concerning recruitment, training, facilities, equipment, program coordination, and the scientific program. The review recommended increased scientific emphasis on emerging chemicals, genomic techniques, effects of energy activities, development of a demonstration site for comparing biomarkers and ecological effects, mercury, invasive species controls, underrepresented species, and the Biomonitoring of Environmental Status and Trends program (subsequently moved to the Status and Trends Program). As of 2004, the CBP has begun to develop genomic and molecular biology capabilities at three centers, has increased its efforts relative to polybrominated diphenylethers and other emerging chemicals, and has begun the planning for a demonstration project in collaboration with the Status and Trends Program and NAWQA, and has supported a workshop on mercury. Scientific recommendations from the review were the basis for the annual Program Direction of 2003 and 2004. The recommendations and framework of the Program Review also played an important role in the development of the current 5-yr plan by providing input on the basic structure and partner needs, and developing program goals, objectives and strategies. The program review document can be found on the Internet at: http://biology.usgs.gov/contam/about.htm.

Communication with Scientists and Partners

The CBP communicates information about program goals and objectives to CBP scientists and partner agencies through its web sites, the Annual Program direction, workshops and the President's Budget to Congress. Science developed by the CBP is communicated in briefings for partners, sessions for information exchange at scientific meetings, the USGS/EPA Mercury Roundtable, training sessions at the FWS National Conservation Training Center and elsewhere, peer-reviewed publications, science fact sheets, cyber seminars, workshops and other briefings. The Program Coordinator, Center Directors and Regional personnel describe the status of current research, and coordinate scientific issues with participating BRD scientists and partner agencies. Program scientists provide much of the direct technical assistance and information transfer to partner agencies and client organizations.

Goals, Objectives, and Strategy for Science in the Contaminant Biology Program

Contaminant Biology is a multidimensional science. Projects could be classified according to chemical class, scientific discipline, type of organism or habitat, or many other factors. The scheme below follows the gradient from relatively controlled laboratory studies of toxicology and chemistry, to studies in particular places, to multi-stressor aspects of our science, which remain our biggest challenges. No scheme will perfectly classify CBP activities and at the same time, enable scientists to explore the fertile intersections between scientific subdisciplines.

Goal 1. Toxicology and Chemistry

Develop methods and generate information to determine sources, fate, exposure and effects of environmental contaminants. Develop and standardize biomarkers, molecular biology methods and other analytical and toxicological assays.

Toxicology and chemistry studies are the basis of our understanding of environmental fate and biotic effects of contaminants. Tools and information developed under this goal are used to assess environmental risk and form the foundation for the other CBP goals. Research on chemical degradation reveals pathways that modify contaminant concentrations and intrinsic toxicity. Toxicological studies describe the variation in sensitivity among species. Controlled investigations of contaminant toxicology and environmental chemistry, primarily conducted in the laboratory, underpin field studies of fish and wildlife within the contaminated habitats goal (Goal 2). Research on biomarkers elucidates effects of contaminants on physiological functions, such as endocrine disruption, and how contaminants affect growth, reproduction, immunity and other life processes.

Objective 1A. Identify and quantify contaminants in water, sediments, and biota and other environmentally relevant samples, through the development and application of validated analytical methods and techniques.

Strategy:

1) Develop and standardize analytical methods for emerging contaminants, such as brominated diphenylethers, hormones, pharmaceuticals, personal care products, new generation agricultural chemicals, cyanide species and nanotechnology compounds.
2) Develop and standardize sampling techniques to quantify emerging environmental contaminants and uptake rates in environmental matrices.
   a) Determine the range of applicability and develop the information to interpret data from passive integrative sampling technologies for contaminants through laboratory verification, field-testing and calibration.
   b) Develop technologies to understand toxicity of extracts of field samples.
3) Improve analytical chemistry techniques to measure, reduce detection limits, and lower analytical and sampling costs for single chemicals, classes of chemicals and mixtures of chemicals that are commonly found in the environment.
4) Incorporate toxicity identification evaluations (TIE) with analytical, biochemical and cellular assays to assess potential effects of individual compounds and mixtures.

Objective 1B. Develop, validate and standardize molecular, biochemical and physiological methods to determine toxicity and exposure in species of concern or their surrogates.

Strategy:

1) Undertake a critical review of existing biomarkers to determine gaps and which measures/endpoints yield the most valuable information on contaminant exposure and effects.
2) Relate biomarker results and other physiological, biochemical, and molecular endpoints of contaminant response to effects on the whole organism and ecologically relevant responses.
3) Develop and standardize methods to assay effects of new generation pesticides and emerging contaminants on the endocrine system and determine the implications for growth development and reproduction.
4) Develop, standardize and apply biomarker techniques for detection of exposure and effects to "new generation" pesticides and emerging contaminants.
5) Characterize physiological, biochemical and molecular endpoints for metal exposure and effects on organisms (see also Objective 2G).

Objective 1C. Determine mechanisms of action and toxic effects of priority contaminants on organisms, populations and communities.

Strategy:

1) Determine the toxicity of individual priority contaminants where data and methods are lacking or are inadequate to support the development of criteria protective of aquatic and terrestrial species ("unstudied" industrial effluents, pharmaceuticals, flame retardants and pesticides, including active ingredients, "inerts", adjuvants and end products).
2) Determine concentrations that represent thresholds of toxicity in tissues and environmental media for species of concern and healthy ecosystems.
3) Determine the toxicity and risk of nanotechnology products, and crops that have been genetically modified to produce pesticides or other chemicals.
4) Characterize the effect of route of exposure (water, diet and dietary quality, sediment, maternal transfer, etc.) on toxicity to terrestrial and aquatic fauna. Determine the contribution of each route to overall exposure.

Objective 1D. Determine the relative sensitivity of different species and life stages to contaminants.

Strategy:
1) Conduct toxicity tests and measure biomarker response to support the development of protective criteria for species that are poorly represented in the toxicological literature. Species of particular concern include freshwater mussels, marine mammals, raptors, seabirds, amphibians and reptiles.
2) Develop toxicity information for assessment and interpretation of monitoring data or biomarker results.

Goal 2. Contaminated Habitats

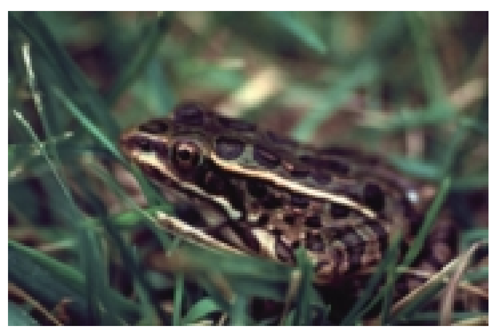
Develop the scientific basis for assessment, restoration and monitoring of habitats that are contaminated by mining, agriculture, urban wastewater, industry, and chemical control agents. Develop toxicological criteria to remediate or prevent contaminant effects.

Information developed under the Contaminated Habitats Goal is used to guide management, remediation, restoration and monitoring of contaminated sites by FWS, BLM, and other land management agencies. The information is used within the NRDAR process, which is a priority for DOI. The CBP collaborates closely with FWS, EPA and many other agencies in its studies. Studies in contaminated habitats assess the fate and effects of chemical contaminants. These studies directly support management action in a variety of different types of environments. Many of these studies culminate in a Damage or Risk Assessment.

Objective 2A. Provide scientific information for NRDAR at CERCLA sites and assessment, remediation and restoration of other contaminated sites. Determine the risk of environmental contaminants to fish and wildlife resources on DOI lands.

Strategy:

1) Develop monitoring protocols and frameworks for selecting monitoring protocols, sentinel and indicator species to assess the hazard and risk of contaminants on DOI resources while minimizing lethal collection of biota.
2) Provide scientific information to help DOI Bureaus set priorities for management and restoration, assess the presence, sources, fate, exposure and effects of targeted contaminants at historically polluted sites (e.g., Coeur d'Alene Basin, Idaho; Kesterson NWR; Palmerton, Pennsylvania; Lake Roosevelt, Fox River) that have undergone remediation or special management to determine if and how contamination, exposure and effects have changed.
3) Design and conduct synoptic surveys and monitor areas of concern, such as critical habitats and indicator or sentinel species to define the presence of emerging contaminants and the potential consequences of these environmental stressors in partnership with EPA, USGS programs, and other partners.
4) Improve methods of linking compounds in environmental samples to the source of contamination ("fingerprinting") in collaboration with EPA scientists working with the Stressor Identification Methodology.
5) Demonstrate how contaminant injuries to individuals affect population level parameters, such as the link between cancer, mortality, and population age structure in Great Lakes fish.
6) Develop tools and strategies to prevent or remediate contamination.
7) Develop methods and tools to improve the effectiveness of restoration.
8) Develop restoration baselines, endpoints, goals and criteria for measuring and evaluating restoration success and ecological recovery, incorporating toxicological effects, land use and the natural variability in ecosystems. Develop tools to estimate the timeframes for recovery.
9) Evaluate effects of atmospheric deposition of contaminants in susceptible aquatic and terrestrial habitats, especially those on DOI lands.
10) Improve modeling and predictive programs for use in assessing contaminant damages and in predicting restoration success.



Objective 2B. Investigate the effects on nontarget terrestrial and aquatic fauna of the use of agricultural, rangeland and forestry chemicals.

Strategy:

1) Document the effects of agricultural chemicals and nutrients on adjacent and downstream wetland fauna and ecosystems in the Great Lakes and coastal areas.
2) Examine the effects of pulses of pesticides and nutrients to populations and communities of receiving waters such as Chesapeake Bay.
3) Examine contaminant mixtures in "non-point source" and irrigation return flows and their effects on the fauna of receiving waters, including endangered species.
4) Evaluate the toxicity and potential population and community effects of pesticides, chemical control agents and fire retardants applied to forests, rangeland and aquatic environments.

Objective 2C. Quantify ecological changes caused by contamination associated with energy development and use, and develop new tools for designing and evaluating remediation.

Strategy:

1) Evaluate effects of contamination (including production water from coal bed methane) from energy production sites on Federal land, including National Wildlife Refuges.

Objective 2D. Evaluate ecological effects caused by mercury in susceptible aquatic and terrestrial habitats.

Strategy:

1) Enhance collaboration and coordination of researchers within USGS working on mercury by working with modelers through the development of workshops and other avenues for communication.
2) Determine the survival, species-specific sensitivity and adverse effects of exposure to methylmercury in vulnerable life stages of birds, fish, amphibians and reptile populations in the laboratory and field. Characterize thresholds for toxic effects of mercury in fish and wildlife based on concentrations in tissues.
3) Compare effects of methylmercury in contaminated environments with differing mercury sources and differing climatic, geologic and ecological characteristics.
4) Map and model mercury contamination in fish.
    a) Develop pharmacokinetic models of methylmercury to predict diet to blood and diet to egg relationships in fish-eating birds.
    b) Cooperate with partners to model methylmercury movement through the aquatic food chain and to predict potential toxic effects on vulnerable human populations such as Native American tribal units.
    c) Map the extent of mercury contamination on DOI lands
    d) Develop an Internet site with USGS mercury information, information on mercury in fish nationwide, with a model that standardizes fish concentration so that concentrations can be compared in different parts of the country.
5) Identify and evaluate potential landscape management approaches for reducing production of methylmercury in the aquatic ecosystem while supporting restoration alternatives. Provide scientific information to help DOI Bureaus set priorities for management and restoration related to mercury.
    a) Identify important factors that contribute to the bioaccumulation of methylmercury in different regions, in collaboration with partners.

Objective 2E. Evaluate ecological effects associated with urban and industrial development.

Strategy:

1) Determine effectiveness of habitat alterations and urban planning in reducing contaminants and maintaining healthy aquatic populations.

2) Develop and evaluate monitoring tools for assessment of urban storm water discharge management and treatment.

Objective 2F. Characterize exposure, bioavailability and ecological effects of metals, minerals and chemicals associated with mining (e.g., cyanide) at contaminated sites, including mine lands.

Strategy:

1) Conduct population or community-level field studies of biota exposed to metals.
2) Determine the implications of metal and cyanide speciation, and aging on exposure, bioavailability, porewater concentrations, toxicity test results, and effects on resident biota using a weight-of-evidence approach.
3) Develop a research-based conceptual model of the interacting effects of mixtures of metals.

Goal 3. Integration of Ecological Stressors

> *Improve the scientific basis for evaluating the effects of multiple stressors at all levels of biological organization and at multiple temporal or spatial scales.*

Our limited understanding of the complexity of interactions between and among environmental stressors highlights the need to focus on this issue. Analysis of interactions among ecological stressors can focus at several scales. For example, some habitat-wide investigations integrate the effects of physical, chemical and biological stressors, such as the interactions between UV radiation and water quality or pathogens. Other studies examine the interaction of stressors on a particular species. Still other studies compare effects at different spatial scales, or evaluate the risk of chemical contaminant mixtures.

Objective 3A. Develop models and other tools for predicting environmental exposure to, effects of contaminants and ecosystem recovery.

Strategy:

1) Develop spatial tools and databases to document the geographic extent of contaminant effects and factors affecting bioavailability. Develop map overlays of contaminant and species distributions for lead and zinc mining in the mid-continent, iron and copper in the upper Midwest, selenium/phosphate mining, metal and acid contamination from coal mining in the East, and exposure of trust resources to endocrine disrupting chemicals. Compile, synthesize and analyze existing exposure and effects data to assess local and national risk. Relate to the National Map, Gap Analysis or other spatial databases.
2) Synthesize toxicity information to aid in interpretation of chemical concentration data in environmental media.
3) Design and use models to predict the effects of contaminants and other stressors on populations, communities and ecosystems and ecological recovery in environments with multiple stressors.

   a) Improve fate and transport models, especially those describing contaminant actions at air/water and water/sediment interfaces.
   b) Design biological models that incorporate different routes of exposure and life cycle stages.
   c) Design better ecological risk assessment techniques (e.g., probabilistic methods); determine how endpoints change with differing levels of reduction in contaminants. Incorporate multiple effects measurements from field-collected organisms into population models and use them within risk assessments.

Objective 3B. Examine ecological and toxicological effects of chemical mixtures or the combination of chemical and nonchemical stressors in organisms, populations of species of concern, and communities, and establish the link to biomarker results.

Strategy:

1) Establish linkages between effects of particular contaminants at different levels of organization (molecular, cellular, physiological, organismal, population, and community) and biomarkers.
2) Assess the effects of contaminants that co-occur in complex mixtures in sediment and other matrices from industrialized areas.
   a) Integrate laboratory and field studies to measure overall risk of chemical mixtures to individuals and populations, emphasizing site-specific research in areas receiving treated sewage effluent, paper mill effluent, and other types of wastewater effluents. Conduct toxicity tests with mixtures found in terrestrial and aquatic habitats, and develop ways of extrapolating the results of single chemical testing to chemical mixtures.
   b) Determine the synergistic and antagonistic effects of mixtures of inorganics (e.g., mercury and selenium) on the health and reproduction of birds. Associate field exposures with ecological effects through multiple lines of evidence.
   c) Develop laboratory/field relationships of endocrine effects to individuals and extend these studies to populations. Improve interpretation of endocrine perturbations at the population level leading to population models that ultimately can be used in risk assessment.
   d) Determine effects of low level, chronic exposure of complex mixtures on nervous and immune systems.
   e) Conduct field evaluations to establish which early changes or endpoints in individuals are the most predictive of population-level effects.
   f) Evaluate the interactions of potentially toxic pharmaceutical and personal care product contaminants on sensitive individuals and populations of aquatic vertebrates and invertebrates.
3) Examine the influence of chemical and nonchemical stressors. Examine ecological effects of multiple stressors on trophic level interactions.
   a) Characterize the physical and chemical influences on the bioavailability and toxicity of metal mixtures.
   b) Determine the effects of multiple stressors (including habitat alterations, invasive species) on multiple species (invertebrates to mammals) in the South Florida Everglades in collaboration with ATLSS model investigators.

c) Characterize interactions of environmental contaminants with UV exposure.
d) Determine the role of interacting natural and anthropogenic stressors in modulating disease resistance, predation, reproductive success, and other measures of animal health and performance.
e) Determine the cause of population declines of amphibians and reptiles in concert with other ecological studies. Identify surrogate species to help assess multiple stressor effects on endangered species.
f) Determine the relative contributions of contaminants and nutrients in affecting aquatic organisms, populations, and communities.

Opportunities for Collaboration among USGS Programs

Goal 1. Toxicology and Chemistry

> ***Develop methods and generate information to determine sources, fate, exposure and effects of environmental contaminants. Develop and standardize biomarkers, molecular biology methods and other analytical and toxicological assays.***

Interactions with other USGS Programs, such as Fisheries: Aquatic and Endangered Resources, and the Wildlife and Terrestrial Resources Program, are needed to understand the perturbations caused by contaminants. The National Water Quality Assessment Program (NAWQA) and monitoring data from the Status and Trends of Biological Resources Program are interpreted using scientific information from CBP.

Goal 2. Contaminated Habitats

> *Develop the scientific basis for assessment, restoration and monitoring of habitats that are contaminated by mining, agriculture, urban wastewater, industry, and chemical control agents. Develop toxicological criteria to remediate or prevent contamination effects.*

Many programs have interests related to contaminated habitats. Eastern Region of USGS and several DOI Bureaus have identified mercury as a high priority. The CBP has studies in Puget Sound, the Great Lakes, Chesapeake Bay, San Francisco Bay, Missouri River, South Florida, and other regional priority areas. Assessing conditions on contaminated sites often requires the involvement of multiple USGS programs, such as Mineral and Energy Resources (assessment of geochemical hazards), Toxic Substances Hydrology (processes that affect contaminant transport and fate), the Cooperative Water Program (water quality studies), Priority Ecosystems Science Program (regional studies), Coastal and Marine Geology (coastal and marine contamination) and others. All of these USGS Programs have goals that support the needs for information, or utilize the information from the CBP. The GIO, and the Geographic Analysis and Monitoring (GAM) Program support the development of spatial tools to document the geographic extent of contamination, such as the development of their website entitled, "Environmental Mercury Mapping, Modeling, and Analysis."

Goal 3. Integration of Ecological Stressors

> *Improve the scientific basis for evaluating the effects of multiple stressors at all levels of biological organization and at multiple temporal or spatial scales.*

These studies link CBP with other USGS programs, such as Terrestrial, Freshwater and Marine Ecosystems (ecological structure and function) and Status and Trends (Biomonitoring of Environmental Status and Trends), Mineral Resources (assessment of abandoned minelands) and Energy Resources (assessment of energy exploration and production, such as coalbed methane), and the NAWQA Program (concentrations of chemicals in the environment). The Fisheries, Aquatic and Endangered Resources Program, and the Wildlife and Terrestrial Resources Program contribute information on biotic factors that are important to understanding contaminant effects. The CBP uses information from inventory and monitoring programs to identify scientific issues related to effects to biota and natural resources. NAWQA and CBP formally interact through three BRD Regional Biologists for NAWQA, who facilitate interactions and projects between NAWQA and BRD scientists to develop projects that supplement chemical data with biomarkers, toxicity tests, fish health, population modeling, etc. The goals of the CBP are also supported by a mercury project carried out by scientists

Description of Scientific Directions and Potential Future Initiatives

New Chemicals

Science in the CBP continues to evolve to meet new challenges. Information is needed to understand the risks posed by newly manufactured chemicals or emerging environmental threats. Pharmaceuticals, personal care products, new pesticides, nanotechnology devices and brominated diphenylethers are the foci for new research in toxicology and chemistry. Information is needed to identify, and determine the fate and effects of emerging chemicals.

Untested Species

Although CBP scientists have historically developed testing methods and supplied data on native fish and wildlife, the program continues to emphasize the development of new methods and resulting toxicity data for imperiled species or groups such as amphibians, seaducks and freshwater mussels, for which no methods have been established in the scientific literature. The CBP will continue to develop new ways to understand and predict differential sensitivity across species. This information should improve the understanding of the physiological/genetic or environmental basis of toxic response. Work should help determine the adequacy of surrogates for assessment and criteria.

Genetically Modified Organisms

Genetically modified organisms are being designed to produce pesticides, pharmaceuticals or have capabilities that extend their value to meet other societal needs. Though in many cases these organisms are regulated in a similar way as the special products they produce, the essential difference is that in some cases, the organisms producing those products can now reproduce, hybridize and move their products beyond where the organisms are released. Better information is needed on the environmental effects of these organisms and their products.

New Methods

The use of molecular biology techniques for human health and agricultural applications has blossomed in recent years. As a spin-off, environmental scientists have started to use these techniques for answering fundamental questions related to effects of multiple stressors and contaminant mixtures. The CBP will support development of molecular biology capabilities and methods for determining contaminant exposure and for tying molecular-level effects to effects at higher levels of biological organization.

Science for Restoration of Contaminated and Degraded DOI Lands

Improved health and sustainability of lands and resources under DOI stewardship increases the value of these resources. However, on many DOI lands, a legacy of toxic substances, abandoned mine lands, and waste dumps prevents the Nation from enjoying the full benefits that DOI lands can sustain. Scientific information is needed to inform assessment, goal-setting, determination of baseline conditions, monitoring and restoration of contaminated ecosystems for Departmental NRDAR activities. The CBP will convene a workshop on restoration of contaminated sites to develop the conceptual framework for building this area of science and to improve cross-ecosystem understanding of restoration lessons learned. Scientific areas that are critically important for management, injury determination and restoration of the Department's contaminated lands and trust resources include:

1) Data and information tools for land managers, including a geo-referenced database of restoration performance data throughout the country and tools to analyze the effectiveness of restoration efforts.
2) Monitoring protocols, endpoints and models for measuring restoration success, including determination of thresholds for ecological recovery, baseline environmental conditions (ecological and contaminant concentrations prior to chemical contamination); and rates of recovery following remediation.
3) Remediation and restoration techniques that optimize ecological success and cost-effectiveness.

Multiple Stressors

Organisms in most contaminated environments are exposed to a mixture of chemical contaminants and other environmental stressors. Though this is not a new problem, it needs new solutions and new approaches in order to make progress. The CBP will continue to focus on innovative ways to approach these types of sites.

Program Resource Needs

Facilities and Equipment

Facilities at Patuxent have deteriorated beyond reasonable repair or rehabilitation, and a modernization of Patuxent facilities will be needed to bring the contaminant biologists back to the Patuxent Campus. The new facilities is a high priority for the CBP. Buildings at Columbia River Research Laboratory in Cook, Washington, are also in need of updating. Continued investment in capital equipment, especially the equipment for molecular biology and analytical technology for emerging chemicals is needed to maintain scientific excellence.

Expertise and Capabilities

The demographic balance of our workforce is a **major** challenge. Recruitment of young scientists is sorely needed to maintain our ability to meet the contaminant information needs of our partners into the future. Recruitment and hiring of young scientists was the strongest recommendation of the Program review report and remains the highest priority of the Program. A recent hire in the application of genetics and genomics to contamination problems at the Columbia Center will significantly augment our aquatic molecular biology efforts, but expertise is also needed on the terrestrial side. Additional expertise is needed to conduct research on multiple stressors and modeling of toxic effects on populations and ecosystems. The expertise at the Centers is significantly augmented by collaborations with scientists inside the USGS (such as in the USGS Cooperative Research Units), and outside of the USGS in academia and in other Federal and State agencies. These interdisciplinary collaborations enable researchers to interact with collaborators in complementary disciplines to ensure the appropriate depth and breadth of analysis and approach, and to gain access to needed scientific facilities and expertise.

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[i] From *Developing Effective and Responsive Partnerships*, a report on the results of a 1996 survey of information needs identified by a variety of types of state agencies relative to BRD science.

[ii] Fellows, Valerie L. 2003. Pollution and contaminants contributing to species decline: an analysis of threatened and endangered species recovery plans. MS Thesis, University of Maryland 192pp.

[iii] Williams, J.D., and R.J. Neves. 1995. Freshwater Mussels: A Neglected and Declining Aquatic Resource. Fisheries, pages 177-179 *In* E.T. LaRoe, et al, Our Living Resources, A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems, US Dept. of the Interior, National Biological Service. Washington, DC. 530pp..