COLORADO RIVER ECOSYSTEM SCIENCE SYMPOSIUM 2003

Sheraton Tucson Hotel and Suites, Tucson Arizona
October 28-30, 2003

ORGANIZED BY THE U. S. GEOLOGICAL SURVEY,

GRAND CANYON MONITORING AND RESEARCH CENTER

PROGRAM AND ABSTRACTS

Contents

Program Objectives and Information

The 2003 Ecosystem Science Symposium is the fourth symposium organized by the U. S. Geological Survey, Grand Canyon Monitoring and Research Center to disseminate study results to the Adaptive Management Program participants and the general public. The presentations herein report on the effects of Glen Canyon Dam operations on cultural, biological, and physical resources in Grand Canyon National Park, as directed under the Record of Decision of the Final Glen Canyon Dam Environmental Impact Statement.

The objectives of this symposium are to:

1. Present recent scientific findings by GCMRC-sponsored monitoring and research projects, including those conducted for the Low Summer Steady Flows*.

2. Promote inter-disciplinary discussions among scientists working on different aspects of the Colorado River ecosystem in support of the Glen Canyon Dam Adaptive Management Program.

3. Facilitate more effective collaborations between scientists and managers toward achieving a better-integrated long-term monitoring program.

4. Inform members of the Adaptive Management Work Group (AMWG), Technical Work Group (TWG), and the public on the recent findings of scientists funded by the GCMRC to conduct monitoring and research of the Colorado River ecosystem.

Evening Poster Session on October 28th: For additional information on the Colorado River ecosystem research and monitoring programs, there will be a special poster session on Tuesday, October 28th from 5:15 p.m. to 9:00 p.m. in the symposium meeting room.

*A package of modified flows including steady 8,000 cfs during summer of 2000, designed to benefit the endangered Humpback Chub in the Grand Canyon

GLEN CANYON DAM ADAPTIVE MANAGEMENT PROGRAM (AMP)
and the
GRAND CANYON MONITORING AND RESEARCH CENTER (GCMRC)

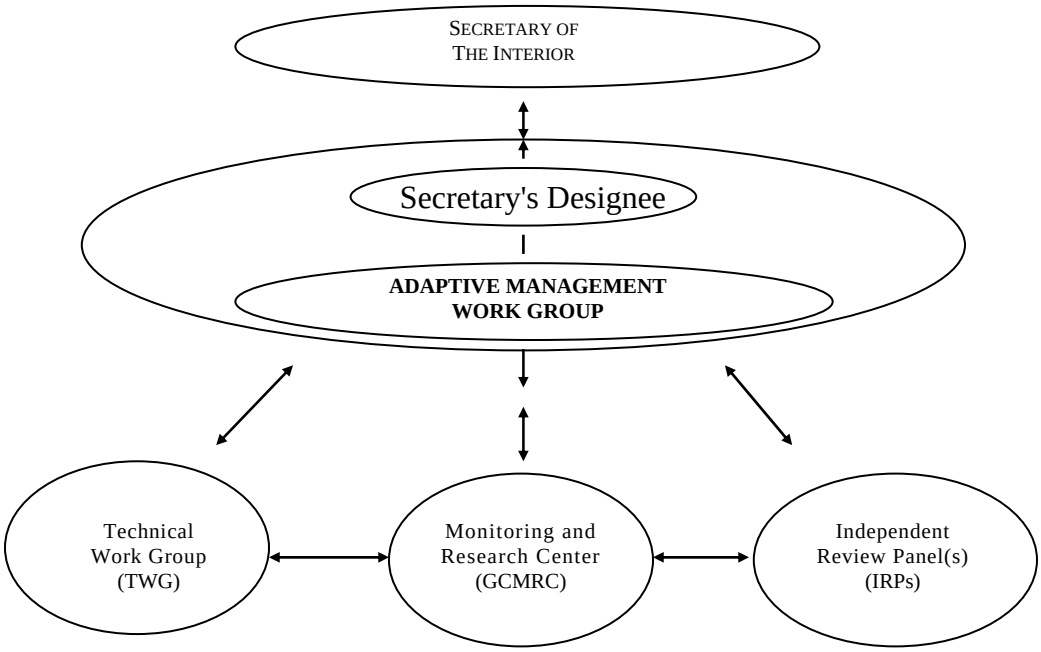
Introduction

The Colorado River corridor from the forebay of Glen Canyon Dam to the upper reaches of Lake Mead harbors significant physical, biological, cultural and recreational resources. Although it is the longest riparian segment in the coterminous United States free of develop-ment, the Colorado River and associated terrestrial ecosystems today differ significantly from their original character. The Glen Canyon Dam, completed in 1963, has had dramatic impacts on downstream resources within the Glen Canyon National Recreation Area and Grand Canyon National Park.

Legislative History

The Grand Canyon Protection Act of 1992 (Public Law 102-575), the findings of the Glen Canyon Dam Environmental Impact Statement (GCDEIS, 1995), and the subsequent Record of Decision (ROD, 1996), called for the creation of an Adaptive Management Program to evaluate the effects of dam operations on the downstream resources of the Colorado River ecosystem. The AMP is comprised of the Adaptive Management Work Group (AMWG), a Federal Advisory Committee, the Grand Canyon Monitoring and Research Center (GCMRC), the Technical Work Group (TWG), and a set of Independent Review Panels (IRPs).

Structure of the Glen Canyon Dam Adaptive Management Program



Establishment of the Grand Canyon Monitoring and Research Center* (GCMRC)

The Secretary of the Interior established the GCMRC in 1995 to provide the science needed to enhance protection and management of resources in the Colorado River corridor primarily between Glen Canyon Dam and Lake Mead.

The mission of the GCMRC is: "To provide credible, objective scientific information to the Adaptive Management Program on the effects of operating Glen Canyon Dam on the downstream resources of the Colorado River ecosystem, utilizing an ecosystem science approach." The roles and responsibilities of GCMRC include:

1. Advocate quality, objective science and the use of that science in the adaptive management decision process.

2. Provide scientific information for all resources of concern identified in the "Operation of Glen Canyon Dam Final Environmental Impact Statement."

3. Support the Secretary's designee and the Adaptive Management Work Group in a technical advisory role.

4. Develop strategic plans, annual work plans and project designs and proposals for implementation by GCMRC and/or its contractors, to provide monitoring and research activities in support of information needs identified by the Adaptive Management Work Group.

5. Coordinate review of the monitoring and research projects and programs with independent review panels, science advisors, and the National Research Council.

6. Coordinate, prepare, and distribute technical reports and documentation for review and as final products.

7. Prepare and forward technical management recommendations and annual reports, as specified in section 1804 of the Grand Canyon Protection Act to the Technical Work Group.

8. Manage all data collected as part of the Adaptive Management Program. Serve as a repository (source of information) for others (stakeholders, students, public, etc.) in various formats (paper, electronic, etc.) about the effects of operating Glen Canyon on the downstream resources of the Colorado River ecosystem and the Adaptive Management Program.

9. Administer research proposals through a competitive contract process, as appropriate.

10. Manage GCMRC finances and personnel efficiently and effectively.

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* For additional information on the GCMRC, contact program Chief, Dr. Jeffrey Lovich at 2255 N Gemini Drive, Flagstaff, AZ 86001, (928) 556-7358, Jeffrey_Lovich@usgs.gov

U.S. Geological Survey Southwest Biological Science Center
Grand Canyon Monitoring and Research Center
Colorado River Science Symposium October 28-30, 2003
Sheraton Tucson Hotel and Suites

Program Schedule

DAY 1 – OCTOBER 28, 2003

8:00 a.m. **Welcome and Introductions – Jeff Lovich, Chief, USGS-BRD SBSC Grand Canyon Monitoring and Research Center**

Plenary Session: **Colorado River Law**
Bennett Raley, Assistant Secretary - Water and Science

MORNING SESSION 1 – PHYSICAL RESOURCES – 8:30 – 10:10 a.m.
Moderator: Ted Melis

8:30 – 8:50 Long-term Aggradation of the Longitudinal Profile of the Colorado River in Grand Canyon, **Christopher Magirl**, **U.S. Geological Survey,** and others

8:50 – 9:10 Frequency of Debris Flows in Grand Canyon, **Peter Griffiths**, Robert H. Webb, **U.S. Geological Survey**

9:10 – 9:30 Overview of Integrated Fine-Sediment Monitoring in Colorado River Ecosystem, **John C. Schmidt, Utah State University,** and others

9:30 – 9:50 Canyon in a Box: Flume Studies of Sand Transport in Grand Canyon and Implications for Modeling and Management, Peter Wilcock and **Paul E. Grams, John Hopkins University**

9:50 – 10:10 Fine-Grained Sediment Inventory and Change Detection in the Grand Canyon River Corridor Using Airborne Digital Imagery, **Michael Breedlove, U.S. Geological Survey**

BREAK – 10:10 – 10:30 a.m.

MORNING SESSION 2 – PHYSICAL RESOURCES – 10:30 a.m. – 12:30 p.m.
Moderator: Ted Melis

10:30 – 10:50 Results from Modeling of Sand Deposition as a Function of Discharge and Sandbar Surveys: How Effective are Powerplant Flows at Making New Sand Deposits? **Stephen Wiele, U.S. Geological Survey;** Joseph Hazel, Jr., Northern Arizona University

10:50 – 11:10 Grand Canyon Geodetic Control Network, **Keith Kohl, U.S. Geological Survey**

11:10 – 11:30 Survey and Hydrography Technology, **Matthew Kaplinski**, **Northern Arizona University,** and others

11:30 – 11:50 The Relative Roles of Channel and Eddy Storage in the Colorado River in Marble Canyon: New Insights from Monitoring Individual Sites and Longer Reaches, **Joseph Hazel, Jr., Northern Arizona University,** and others

11:50 – 12:10 Sediment Mass Balance in Marble and Upper Grand Canyons Using Laser and Acoustic Technologies, **David J. Topping, U.S. Geological Survey,** and others

12:10 – 12:30 Bed-sediment Grain Size and Influence on Sediment Transport, David M. Rubin, U.S. Geological Survey, **Brian Lockwood, University of California Santa Cruz, David J. Topping, U.S. Geological Survey**, and others

LUNCH – 12:30 - 1:40 p.m. *(*POSTER SET UP - time available now or at end of day)*

AFTERNOON SESSION 2 – INFORMATION TECHNOLOGY- 1:40 – 2:40 p.m.
Moderator: Michael Liszewski

1:40 – 2:00 Techniques in Multibeam Hydrographic Data Processing, **F. Mark Gonzales, U.S. Geological Survey**, and others

2:00 – 2:20 Pre- and Post-Low Summer Steady Flows Side-scanning Sonar Imaging of the Colorado River, Grand Canyon, Roberto Anima**, Florence Wong**, **U.S. Geological Survey**, and others

2:20 – 2:40 Geomorphic Change Detection in Grand Canyon: Comparison of 2000 LIDAR and 1923 Survey Data, **Christopher Magirl, U.S. Geological Survey**, and others

BREAK – 2:40 – 3:00 p.m.

AFTERNOON SESSION 3 – INFORMATION TECHNOLOGY- 3:00 – 4:40 p.m.
Moderator: Michael Liszewski

3:00 – 3:20 Data Management at the Grand Canyon Monitoring and Research Center, **Michael Liszewski, U.S. Geological Survey**

3:20 – 3:40 GCMRC Library Scanning Project, **Stephanie Wyse, U.S. Geological Survey**

3:40 – 4:00 Grand Canyon Integrated Database Management System, Christopher Flaccus, **Cory Lochridge, U.S. Geological Survey**, and others

4:00 – 4:20 Building an Integrated Ecological Spatial Database for the Grand Canyon using Spatial Database Engine, Internet Map Server, and Oracle Database Management System, **Steven Mietz**, **U.S. Geological Survey**, and others

4:20 – 4:40 Establishing a Control Point Database, **Kristin Brown,** Cory Lochridge, **U.S. Geological Survey**

4:40 **POSTER SET-UP (same room as symposium)*

POSTER SESSION & SOCIAL HOUR - 5:15 – 9:00 p.m. *(See Poster Session Program)*

DAY 2 – OCTOBER 29, 2003

MORNING SESSION 1 – EXPERIMENTAL STUDIES: SESSION 1 – LOW SUMMER STEADY FLOWS (LSSF) - 8:30 – 10:10 a.m.
Moderator: Bill Vernieu

8:30 – 8:50 Synthesis of Results and Application to River Management, **John C. Schmidt, Utah State University,** Theodore S. Melis, U.S. Geological Survey

8:50 – 9:10 Effects of a Low Summer Steady Flow Experiment on Native Fishes of the Colorado River in Grand Canyon, Arizona, **Melissa Trammell, National Park Service; Richard Valdez, R.A. Valdez & Associates, Inc.,** and others

9:10 – 9:30 Responses of Native and Non-Native Species to Two Managed Flow Regimes Below Glen Canyon Dam, Grand Canyon, Arizona, Marianne Porter**,** University of California Irvine**; Michael Kearsley, Northern Arizona University**

9:30 – 9:50 Modeling Effects of Discharge on Habitat Quality and Dispersal of Juvenile Humpback Chub (*Gila cypha*) in the Colorado River, Grand Canyon, **Josh Korman, Ecometric Research, Inc.**, and others

9:50 – 10:10 Longitudinal and Near-shore Warming Patterns of the Colorado River During LSSF Experiment, **William Vernieu, U.S. Geological Survey**

BREAK - 10:10 – 10:30 a.m.

MORNING SESSION 2 - EXPERIMENTAL STUDIES: SESSION 2 – LOW SUMMER STEADY FLOWS (LSSF) - 10:30 – 11:50 a.m.
Moderator: Susan Hueftle

10:30 – 10:50 Downstream Water Quality Effects of Drops in Lake Powell Elevation, 2003, **Susan Hueftle, U.S. Geological Survey**

10:50 – 11:10 Implications of Low Summer Steady Flows on Whitewater Boating Safety and other Recreational Attributes, **Linda Jalbert, National Park Service**

11:10 – 11:30 Phyto-Benthic Response to the 2000 and 2003 Ecological Restoration Flows in the Colorado River Below Glen Canyon Dam, **Joseph Shannon**, **Northern Arizona University**, and others

11:30 – 11:50 Economic and Financial Effects to Electrical Power Production from Experimentation at Glen Canyon Dam; LSSF and Proposed Sediment Retention Flows and Non-Native Fish Removal Flows, **Clayton Palmer, Western Area Power Administration,** and others

LUNCH - 11:50 a.m. – 1:30 p.m.

AFTERNOON SESSION 1 - EXPERIMENTAL STUDIES: SESSION 3 – MANIPULATIONS AND FLUCTUATING FLOWS – 1:30 – 2:30 p.m.
Moderator: Lew Coggins

1:30 – 1:50 Brown Trout Removal in Bright Angel Creek, Grand Canyon National Park: A Potential Recovery Effort for Native Fishes, **William Leibfried, SWCA Environmental Consultants,** and others

1:50 – 2:10 Mechanical Removal of Non-native Fishes in the Colorado River within Grand Canyon: An Update on 2003 Operations and Results, **Lew Coggins,** Michael Yard, **U.S. Geological Survey**

2:10 – 2:30 Spatial and Temporal Patterns in Rainbow Trout Redds and Fry in the Lees Ferry Reach of the Colorado River: Implications for Fluctuating Flows from Glen Canyon Dam, **Josh Korman, Ecometric Research,** and others

BREAK - 2:30 – 2:50 p.m.

AFTERNOON SESSION 2 - EXPERIMENTAL STUDIES: SESSION 4 – SOCIO-CULTURAL RESOURCES; RECREATION – 2:50 – 4:50 p.m.
Moderator: Helen Fairley

2:50 - 3:10 High-resolution Photogrammetry and the Gully Erosion of Cultural Sites, **Joel Pederson, Utah State University**

3:10 – 3:30 Modeling of Sand Deposition in Archaeologically Significant Reaches of the Colorado River in Grand Canyon, **Stephen Wiele, U.S. Geological Survey,** Margaret Torizzo, Vermont Department of Environmental Conservation

3:30 – 3:50 The Role of Eolian Sediment Transport in the Preservation of Archeological Features: A New Research Initiative in Grand Canyon National Park **Amy Draut, U.S. Geological Survey,** and others

3:50 – 4:10 Adopt A Beach Project: Long Term Monitoring of High-Demand Camping Beaches in Grand Canyon, **Kate Thompson, Grand Canyon River Guides, Inc.**

4:10 – 4:30 Towards an Understanding of Social Impediments to Adaptive Management in Grand Canyon, **Christopher Updike, Northern Arizona University**

4:30 – 4:50 Interactive Archaeology of the Colorado Plateau and Grand Canyon: Archaeological and Indigenous Perspectives, **George Gumerman IV, Northern Arizona University**

Panel Discussion: Cultural Resource Treatment Options -7:30 – 9:30 p.m. *(symposium room)*
- Panelists and their affiliations are shown following the Authors List

DAY 3 – OCTOBER 30, 2003

MORNING SESSION 1 – EXPERIMENTAL STUDIES: NATIVE FISHES – 8:30 – 10:10 a.m.
Moderator: Mike Yard

8:30 – 8:50 Trends in the Recruitment and Abundance of the Little Colorado River Humpback Chub Population, **Lewis G. Coggins, Jr., U.S. Geological Survey;** Carl Walters, University of British Columbia

8:50 – 9:10 Long-Term Monitoring to Determine Status, and Trends of Native Fish in the Colorado River through Grand Canyon, Arizona, **Helene Johnstone, SWCA Environmental Consultants**

9:10 – 9:30 Anticipated Effects of a Temperature Control Device on Fishes of the Colorado River through Grand Canyon, Arizona, **R.A. Valdez, R.A. Valdez & Associates, Inc.,** and others

9:30 – 9:50 Current Status and Trends of Lake Powell and Glen Canyon Dam Release Water Quality, **William Vernieu, U.S. Geological Survey**

9:50 – 10:10 The Utility of Bioenergetics Models in Grand Canyon Fisheries Research, **Jim Petersen, U.S. Geological Survey,** and others

BREAK - 10:10 – 10:30 am

MORNING SESSION 2 – EXPERIMENTAL STUDIES: NATIVE FISHES – 10:30 – 11:50 a.m.
Moderator: Steve Gloss

10:30 – 10:50 Recovery Goals for Humpback Chub and Adequacy of Management Actions in Grand Canyon, Arizona, **Richard Valdez, R.A. Valdez & Associates, Inc.,** and others

10:50 – 11:10 Genetic Interrelationships of *Gila cypha* in the Colorado River Ecosystem, **Marlis R. Douglas,** Michael E. Douglas, **Colorado State University**

11:10 – 11:30 Effective Population Sizes for *Gila cypha* in the Colorado River Ecosystem, **Michael E. Douglas**, Marlis R. Douglas, **Colorado State University**

11:30 – 11:50 Site Fidelity of Humpback Chub in Grand Canyon, **Craig Paukert,** Lewis G. Coggins, Jr., **U.S Geological Survey**

LUNCH - 11:50 a.m. – 1:10 p.m.

AFTERNOON SESSION 1 – NON-NATIVE FISHES – 1:10 – 2:30 p.m.
Moderator: Craig Paukert

1:10 – 1:30 Status, Trends and Long-term Monitoring of the Lees Ferry Tailwater Fishery, 1991-2003, **Joe E. Slaughter, IV, Arizona Game and Fish Department,** and others

1:30 – 1:50 One-Fish, Two-Fish, Red-Fish, Blue-Fish: An Evaluation of the Utility of Snorkel Surveys for Estimating Population Size and Tracking Trends in Relative Abundance of Rainbow Trout in the Lees Ferry Reach of the Colorado River, **Josh Korman, Ecometric Research;** Michael Yard, U.S. Geological Survey

1:50 – 2:10 Long-term Monitoring of Rainbow Trout, Brown Trout, and Common Carp in the Grand Canyon, **R. Scott Rogers, Arizona Game and Fish Department;** David Speas, Utah Division of Wildlife

2:10 – 2:30 Diet and Incidence of Predation for Rainbow and Brown Trout Near the Little Colorado River, Grand Canyon During Winter 2003, **Michael Yard**, **U.S. Geological Survey,** and others

BREAK - 2:30 – 2:50 p.m.

AFTERNOON SESSION 2 – BIOLOGICAL RESOURCES – 2:50 – 4:10 p.m.
Moderator: Mike Yard

2:50 – 3:10 1996-2000 Avifaunal Monitoring Along the Colorado River, **John Spence**, **National Park Service**

3:10 – 3:30 Stranding of Rainbow Trout during Experimental Fluctuating Releases from Glen Canyon Dam on the Colorado River, **Wendy Batham**, **EcoPlan Associates, Inc.**

3:30 – 3:50 The Hopi Tribe Monitoring Project, **Kristin Huisinga**, Michael Yeatts, **The Hopi Tribe**

3:50 – 4:10 Distribution and Trophic Interaction of the Invasive New Zealand Mudsnail in the Colorado River, Below Glen Canyon, **Joseph Shannon, Northern Arizona University,** and others

Final remarks by Jeffrey Lovich, Chief, Grand Canyon Monitoring and Research Center

GCMRC Colorado River Science Symposium
Poster Session – October 28, 2003 (5:15 – 9:00 p.m.)
Sheraton Tucson Hotel and Suites, Tucson, AZ

Poster Presentations

Note: This is a complete alphabetical list of poster titles submitted. Abstracts in this section are only for poster presentations. Titles marked † are located in the oral abstracts section.

† Adopt A Beach Project: Long Term Monitoring of High-Demand Camping Beaches in Grand Canyon, **Kate Thompson, Grand Canyon River Guides, Inc.**

Analysis of PIT Tag Data from Bluehead Suckers (*Catostomus discobolus*) in the Little Colorado River in Grand Canyon, 1991-2003, David Ward, **R. Scott Rogers, Arizona Game and Fish Department**

Assessment of the Flannelmouth Sucker Population in the Little Colorado River, **R. Scott Rogers,** Arizona Game and Fish Department

†Building an Integrated Ecological Spatial Database for the Grand Canyon Using Spatial Database Engine, Internet Map Server, and Oracle Database Management System, **Steven Mietz, U.S. Geological Survey**

Comparison of Electrofishing and Trammel Netting Variability for Sampling Native Fishes in Grand Canyon, Colorado River, Arizona, **Craig Paukert, U.S. Geological Survey**

Designing an Effective Avian Monitoring Program to Meet the Needs of the Grand Canyon Monitoring and Research Center's Adaptive Management Program, Jennifer A. Holmes, U.S. Geological Survey, Matthew J. Johnson, Northern Arizona University

Development and Implementation of Lake Powell Water Quality Database, **William Vernieu, U.S. Geological Survey**

Dissolved Organic Carbon Mass Transfer Under Contrasting Flow Conditions, **Todd Tietjen, Northern Arizona University/U.S. Geological Survey cooperator**

Dynamics of Avian and Arthropod Communities Across Distinct Vegetation Zones Along the Colorado River in Grand Canyon, **Helen Yard, Helen Yard Consultants**; Neil Cobb, Northern Arizona University; Barbara Ralston, U.S. Geological Survey

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†Abstract for this title is located in the oral abstracts section
Presenters are indicated in **boldface** type (no boldface: no presenter in attendance)

Poster Presentations (cont'd)

Effect of a 31,000-cfs Spike Flow and Low Steady Flow on Benthic Biomass and Drift Composition in the Lees Ferry Reach, Colorado River, **R. Scott Rogers, Arizona Game and Fish Department**

Effects of Discharges from Glen Canyon Dam on Potential Rearing Habitat of Humpback *Chub (Gila cypha)* at the Confluence of the Little Colorado and Colorado Rivers in Grand Canyon, Arizona, **Frank Protiva, Shephard-Wesnitzer, Inc.**

Factors Affecting Condition of Flannelmouth Sucker in the Colorado River, Grand Canyon, Arizona, **Craig Paukert, U.S. Geological Survey,** R. Scott Rogers, Arizona Game and Fish Department

†Fine-grained Sediment Inventory and Change Detection in the Grand Canyon River Corridor Using Airborne Digital Imagery, **Michael Breedlove, U.S. Geological Survey**

†GCMRC Library Scanning Project, **Stephanie Wyse, U.S. Geological Survey**

Genetic Assessment of Age-0 Trout Produced in the Grand Canyon Tributaries of the Colorado River, Kyle Hanson, John Epifanio, Julie Claussen, Dave Philipp, Illinois Department of Natural Resources

†Grand Canyon Integrated Database Management System, Christopher Flaccus, U.S. Geological Survey; **Cory Lochridge, U.S. Geological Survey cooperator**

Grand Canyon Riverbed Sediment Changes, Experimental Release of September 2000 – A Sample Data Set, **Florence Wong**, Roberto J. Anima, Peter Galanis, **U.S. Geological Survey**; Jennifer Codianne, Santa Clara Valley Water District;Yu Xia, Mason, Bruce & Girard, Inc.; Randy Bucciarelli, Scripps Institution of Oceanography; Michael Hamer, City of San Leandro

Influence of Topographic Complexity on Aquatic Ecosystems: Solar Insolation Estimates for the Colorado River, **Michael Yard,** Glenn Bennett, Steven Mietz, Lew Coggins, **U.S. Geological Survey;** Lawrence Stevens, Stevens Ecological Consulting; Susan Hueftle, U.S. Geological Survey; Dean Blinn, Northern Arizona University

Integrated Monitoring of Terrestrial Riparian Resources Along the Colorado River in Grand Canyon, **Michael Kearsley, Northern Arizona University**; Helen Yard, Helen Yard Consultants; Neil Cobb, Northern Arizona University; David Lightfoot, Sandra Brantley, Jennifer Frey and Geoff Carpenter, University of New Mexico

Lake Powell Assessment Findings 1964-Present, **Susan Hueftle, U.S. Geological Survey**

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†Abstract for this title is located in the oral abstracts section
Presenters are indicated in **bold face** type (no boldface: no presenter in attendance)

Poster Presentations (cont'd)

Living in Paradise: the Endangered Kanab Ambersnail in Grand Canyon, **Clay Nelson**, Jeffrey Sorenson, **Arizona Game and Fish Department**

†Multibeam Hydrographic Mapping Technology Used on the Colorado River Channel in Grand Canyon, (*see oral presentation abstract title: Techniques in Multibeam Hydrographic Data Processing*) **F. Mark Gonzales, U.S. Geological Survey**

NPS River Corridor Cultural Monitoring and Remedial Action Program, **Lisa Leap,** Jennifer Dierker, Nancy Andrews, **National Park Service**

†The Role of Eolian Sediment Transport in the Preservation of Archeological Features: A New Research Initiative in Grand Canyon National Park, **Amy E. Draut**, David Rubin, **U.S. Geological Survey**; Janet Balsom, National Park Service; Theodore S. Melis, U.S. Geological Survey

Seasonal Light Variation in a Canyon-Bound River: Potential Effects on Distribution, Growth and Colonization of Photoautotrophs, **Michael Yard**, Glenn E. Bennett, Steven N. Mietz, Lewis G. Coggins, Jr., Susan Hueftle, **U.S. Geological Survey**

Translocation of Humpback Chub (Gila cypha) Above Chute Falls, Little Colorado River, **Pam Sponholtz, U.S. Fish and Wildlife Service**; Kara Hilwig, Northern Arizona University Graduate Student

ORAL PRESENTATION

ABSTRACTS

Long-term Aggradation of the Longitudinal Profile of the Colorado River in Grand Canyon

Christopher S. Magirl, Robert H. Webb, Peter G. Griffiths, U.S. Geological Survey-WRD, Tucson, AZ

Abstract. Rapids on the Colorado River in Grand Canyon represent the accumulation of coarse particles due to episodic debris flows. The net effect of coarse-particle inputs is apparent in the longitudinal profile of the river, originally surveyed in 1923 and measured again in 2000 using LIDAR. Individual rapids represent small-scale convexities in the longitudinal profile with spatial scales of one river kilometer or less; these features exhibit considerable changes that occur on time scales of years and decades and result from frequent debris-flow deposition and river reworking. Rapids serve as local base levels that focus the river's energy into transport or removal of coarse sediment. Intermediate-scale convexities in the longitudinal profile are generated at large debris fans (e.g., Prospect Canyon, Nankoweap), where significant alluvial input and debris-fan reworking create multiple secondary rapids and alternating debris bars. These secondary features extend several river kilometers downstream from source tributaries. Finally, large-scale convexities, with spatially wavelengths ranging from 30-120 river kilometers are also apparent. In comparison with a straight-line gradient originally proposed by Leopold, the overall longitudinal profile shows two major and three lesser large-scale convexities. The amplitudes of these convexities have not changed historically. Two major river-profile convexities are spatially associated with high probability of debris-flow occurrence and large Holocene debris fans. The three lesser large-scale convexities are spatially associated with high debris-flow probability alone. Comparison to a straight-line gradient indicates maximum fill depths of about 30 m; previous seismic work suggests that local fill depths may be as deep as 45 m. These river-profile convexities are the present-day manifestation of a Colorado River subject to episodic but persistent aggradation and subsequent incision through the mid-to-late Quaternary. In contrast to the long-held assumption that the river is currently incising into bedrock, our work suggests that the Colorado River through much of Grand Canyon is expending its energy removing small- and large-scale convexities created by alluvial fill.

Frequency of Debris Flows in Grand Canyon

Peter G. Griffiths, Robert H. Webb, U.S. Geological Survey-WRD, Tucson, AZ

Abstract. Coarse sediment is delivered to the Colorado River in Grand Canyon by debris flows from more than 740 tributary side canyons. Like streamflow floods, debris flows also transport silt, sand, and gravel, but they are the only source of cobbles and boulders. This coarse sediment forms the core of debris fans that constrict the river and raise local bed elevations to establish the pool-rapid sequence characteristic of the Colorado River in Grand Canyon. Debris flows can be hazardous to the recreational community, affecting navigation of white water, destroying camping beaches, and potentially trapping hikers. Debris flows in Grand Canyon have damaged water-supply pipelines, destroyed hiking trails and vehicles, and threatened lives. We evaluate the rate of debris flow occurrence in Grand Canyon for two time periods represented by two distinct records. Direct field observation of all 740 geomorphically significant tributaries on an annual basis from 1984 through 2002 records the occurrence of 93 debris flow events in 83 tributaries for an average of 4.9 events/year. Many of these events created major changes in the river. For the period of 1890 to 1983, we rephotographed and analyzed more than 1,000 historical photographs for evidence of debris flows at 147 tributary junctures and identified 93 debris flows at 84 tributaries. Extrapolated to all 740 tributaries in Grand Canyon, the rate of debris-flow occurrence from 1890 through 1984 was 5.0 events/year, a rate statistically identical to the current rate. However, because annual pre-dam floods would have rapidly removed evidence of smaller debris flows, the pre-1984 rate may actually have been higher. Debris flow frequency does not appear to be uniformly distributed in space, and most debris flows occur during the summer months when the river is most heavily used. Debris flows are unaffected by land-use practices and no watershed management methods are known that would alter the rate of debris flows. Reduction of coarse sediment accumulation—such as gravel favored by spawning salmonids—can only be achieved by periodic flushing flows released from Glen Canyon Dam.

Overview of Integrated Fine-Sediment Monitoring in Colorado River Ecosystem

John C. Schmidt[1], David M. Rubin[2], David J. Topping[3]

[1]Utah State University, Logan, UT
[2]U.S. Geological Survey-GD, Santa Cruz, CA
[3]U.S. Geological Survey-BRD, Flagstaff, AZ

Abstract. Alluvial deposits of sand, silt, and clay comprise a fundamental component of the Colorado River ecosystem in Grand Canyon. These deposits occur as high terraces that are never inundated under the present river regime and as alluvial bars or linear channel-margin deposits, some of which are inundated daily and some of which are only inundated by occasional high dam releases. These deposits play various roles in the natural and human ecosystem of the Colorado River. The extent to which riparian vegetation has colonized these deposits is largely controlled by substrate texture, inundation frequency, and depth to ground water. Alluvial bars are the architecture that creates low-velocity habitat, utilized by some native fish at some life stages. Bare alluvial bars are used as campsites and represent a distinctive attribute of the pre-dam river landscape.

The mass balance of fine sediment in Grand Canyon is:

$$input - output = change\ in\ storage \qquad (1)$$

The input and output of fine sediment is being measured by GCMRC and the USGS as part of the "Sediment Mass Balance" project, and one product of this project is the total estimated change in fine sediment storage in Grand Canyon. The objective of the Integrated Fine-Sediment Monitoring (FIST) project is determination of the components of the right side of (1), which primarily are the bed and the banks, as described:

$$change\ in\ storage = change\ in\ bed\ storage + change\ in\ channel\ margin\ storage + change\ in\ eddy\ bar\ storage \qquad (2)$$

Thus, the FIST project includes integration of measurements of bed and bank storage change.

Since comprehensive measurement of bed and bank storage change is difficult to undertake for all of Grand Canyon, 11 detailed measurement reaches, between 0.7 and 3.9 miles long, have been established that are representative of different geomorphic segments of the Canyon. These study reaches necessarily also represent the longitudinal gradient of increasing fine sediment resupply to the river provided by unregulated tributaries that enter the Colorado River ecosystem.

Several working hypotheses emerge from the FIST project study design, and these hypotheses primarily concern longitudinal and temporal changes in fine sediment storage. We anticipate that the amount of fine sediment stored per unit length of river increases downstream, the total amount of sand deposited in eddies during high flows increases downstream, and that the amount of fine sediment stored on the bed increases downstream. We hope to detect such longitudinal patterns despite inherent system variability caused by the existence of narrow and wide canyon segments.

Canyon in a Box: Flume Studies of Sand Transport in Grand Canyon and Implications for Modeling and Management

Paul E. Grams, Peter R. Wilcock, John Hopkins University, Baltimore, MD

Abstract. A primary objective of the fine sediment modeling project is to predict the migration of tributary sediment inputs to the Colorado River in Grand Canyon. The sand routing model contains a number of interacting components. Although overall model predictions will be tested against measured transport rates at sediment gaging stations, there are few field opportunities to test individual components of the model. To provide greater confidence in the model, we turn to the laboratory to evaluate two critical components of the sand routing model. In the first, we test the algorithm used to predict entrainment of sand from the riverbed. Standard transport models apply to sand-covered beds, whereas the Colorado River bed contains a wide range of sizes from mobile sand to immobile cobble and boulder. In a 14 m flume, we built a sediment bed consisting of 10 cm hemispheres, over which we measured the transport of sand of a size similar to that in Grand Canyon. Our goal was not to build a scale model of field conditions, but to replicate essential features of the bear-bed transport field. We observed a very narrow range of discharge and sand transport rate that define a threshold between a completely sand-covered bed and bed nearly evacuated of sand. Verifications of this threshold at the field scale may play an important role in management actions to either preserve (for later BHBF) or evacuate (for habitat and food base) a sand-covered bed. The experimental observations of transport indicate that existing transport models can provide reliable predications when modified to incorporate the proportion of the bed covered by sand and the elevation of the sand bed relative to the larger roughness. The second flume test will examine model predictions at a larger scale. Field observations indicate that sand inputs from the Paria River migrate through the canyon in a coherent wave. In a large flume (160 m by 3 m), we will produce migrating sand waves over a course, roughened bed. Control over the discharge and sediment input and careful observation of local flow and transport throughout the flume will provide a test of the sand routing model's ability to predict the migration and transformation of sediment waves.

Fine-Grained Sediment Inventory and Change Detection in the Grand Canyon River Corridor Using Airborne Digital Imagery

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Abstract. The Grand Canyon Monitoring and Research Center (GCMRC) produced canyon-wide, digital maps of fine-grained sediment utilizing four-band digital imagery with a spatial resolution of 44 cm flown by ISTAR America in May 2002. Areas of the canyon less than 10 meters above river-surface elevation were analyzed according to their reflective intensity (brightness) and spatial ubiquity (reflective similarity) and classified into sand and non-sand deposits. These classifications were then visually inspected and field-sampled to determine their accuracy.

Results from Modeling of Sand Deposition as a Function of Discharge and Sandbar Surveys: How Effective are Powerplant Flows at Making New Sand Deposits?

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Abstract. Modeling of sand deposition and topographic sandbar surveys demonstrate that releases from Glen Canyon Dam greater than power-plant capacity (bypass) of about 900 cubic meters per second (m^3/s) are significantly more effective than power-plant capacity (PPC) releases at redistributing sand from the channel bed to higher elevations along the channel margin of the Colorado River. A release of 1,270 m^3/s (1.4 x PPC) for 7 days in 1996 tested the effectiveness with which sandbars could be restored by the manipulation of dam releases aimed at redistributing a limited sand supply. This high flow generally resulted in substantial increases in bar size, although some sandbars close to the dam eroded. Since 1996, releases for bar building and habitat maintenance (a 2-day release in 1997, and two 4-day releases in 2000) have been limited to PPC.

A multidimensional model of flow, sand transport, and bed evolution (Wiele and others, 1999) was applied to conditions that occurred during PPC flows and at five bypass discharges. Modeling results show that bypass discharges form larger, higher-elevation deposits than are possible at PPC discharges. Key requirements for substantial deposition of new sand along the sides of this narrow, deeply incised river are sufficient fine-sediment supply and the availability of suitable depositional sites. The potential of PPC releases for building substantial sandbars is complicated by their high efficiency at exporting channel-bed sand and by stage-limited access to deposition sites. Under enriched sediment-supply conditions, transport rates for sand are increased under PPC flows, while accommodation sites for deposition remain limited

To compare the relative efficiency with which various discharges deposit sand for a given sand supply, we computed the length of time required for each discharge to transport the volume of sand transported during the 2000 event. The total time at 906 m^3/s, 108 hours, is longer than the 2000 event because we used a constant transport rate for the model applications that was characteristic of the transport rates after the initial sand transport peak.

An important consideration in planning dam releases to maintain sand deposits is the likely longevity of these deposits. Deposits at higher elevations that are not subject to erosion by water are likely to last longer than lower deposits. Model predictions show that the short, high discharges are more effective at producing deposits at an elevation higher than the 708 m^3/s stage than are PPC releases. The high elevation sand deposition at 2,830 m^3/s is slightly lower than the peak sand volume at 2,120 m^3/s, and declines as discharge declines.

Field measurements indicate that the 1996 bypass release of 1,270 m^3/s (Hazel and others, 1999) significantly increased the area and volume of sand deposits at elevations greater than the stage reached during typical post-dam flows. Minor aggradation occurred during the PPC flows. In 1996, the relative extent of erosion and deposition changed longitudinally downstream as evidenced by the area of substantial deposition exceeding that of erosion at sites farther downstream. The number of bars that were substantially reworked, as measured by the number of bars that significantly increased or decreased in area at the elevation range of normal dam operations, was much greater at 1,270 m^3/s than at 900 m^3/s. Deposition from the 1,270 m^3/s bypass release persisted at many sites on a multiyear scale, whereas deposition resulting from the PPC flows only lasted a few months. These observations show that deposition is sensitive to flow magnitude and depth of inundation as well as to sand supply.

Surveys of sand deposits after the 1,270 m^3/s discharge indicate that this was the only release to result in net high-elevation deposition (above the 708 m^3/s stage elevation). This upper topographic level is the current operating limit for the dam and areas below this level are regularly inundated and reworked by dam releases and typically are not available for camping or colonization by plants. In contrast, surveys indicate that the changes to sand deposits for PPC flows are not significantly different from 0, suggesting that PPC deposits are stage-limited. We hypothesize that the bars were not inundated to sufficient depth for deposition of mobilized sand on the high elevation bar surface.

Grand Canyon Geodetic Control Network

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Abstract. This report evaluates the horizontal and vertical accuracy of control points used in studies of Grand Canyon, Arizona. Topographic, hydrographic and remotely sensed spatially positioned scientific data are collected in the Colorado River ecosystem in support of the Glen Canyon Dam Adaptive Management Program (GCD AMP) (Grand Canyon Monitoring and Research Center, 2000). Control points are located on both the rim of Grand Canyon and along the Colorado River corridor. The control points on the rim of Grand Canyon are distributed across northern Arizona in and throughout Grand Canyon National Park. The control points along the river corridor are distributed along 137 of the 293 miles of the Colorado River ecosystem (CRE). The monumented stations have established positions, which reference the NAD 83 reference system. Scientific data is referenced to these positions for natural and cultural resource monitoring, survey research activities, and remote sensing verification. Many of the control points can accommodate tripod based land survey equipment including total station and laser scanning instruments, reference azimuth stations, and global positioning system receivers.

Accurate spatial positioning of natural and cultural resource monitoring, survey research activities and remote sensing verification is fundamental to performing spatial analysis of changes in the CRE and critical to achieving long-term monitoring objectives. Integrating and analyzing multiple data sets requires an accurate 3-dimensional geodetic reference system. The NAD 83 reference system is used for all spatial data collection and resource monitoring under the direction of Grand Canyon Monitoring and Research Center (GCMRC). The NAD 83 geodetic latitude and longitude coordinates are easily converted to the Arizona State pane central grid with northing and easting coordinates in meters and are used for a variety of survey applications within the CRE.

The report shows that the previous Glen Canyon Environmental Studies (GCES) network control point coordinates are not adequate for use for GCD AMP's long-term monitoring of natural and cultural resources. On the other hand, current static, full wavelength GPS data collection and processing techniques have proved to be invaluable for the purpose of establishing highly accurate positioning of control monuments in Grand Canyon. A sufficient amount of GPS data can typically be collected in less than 24 hours which decreases the uncertainty of control point coordinates to satisfy spatial positioning requirements of the GCD AMP.

Although the coordinate values of the original GCES network are insufficiently accurate, many of the field measurements are reliable and can be utilized in the current GCMRC network. This report demonstrates the remarkable similarity in vector components between the GCES traverse work and the recent GCMRC static GPS work. This validation allows the GCMRC survey department to consciously incorporate the measurements made in the 1990s into the new network to increase the number of control points referenced to the new primary rim control. The historical survey data can be used to both check accuracy of relative positioning techniques and to increase the data set of measurements used in the adjustment.

The stability of the new primary control monuments, the continued resolve to expand survey control in Grand Canyon, and the confidence achieved in the field surveys and coordinate calculations, will ensure that GCD AMP and GCMRC will have a suitable, permanent control network to meet its long-term monitoring objectives.

Survey and Hydrography Technology

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Abstract. The Fine-grained Integrated Sediment Team (FIST) is a cooperative partnership between the GCMRC, U.S. Geological Survey Research and Coastal and Marine Geology Programs, Utah State University, and Northern Arizona University. Recent technological developments in multibeam hydrography, the Global Positioning System (GPS), underwater digital cameras and photogrammetry, in combination with more conventional survey techniques, offer the ability to rapidly map large reaches of the Colorado River in Grand Canyon. These surveying related applications present new opportunities for geomorphological investigation in Grand Canyon because positional data can now be gathered at a rate and scale not previously feasible.

We focus our efforts on 11, 2-6 km reaches of the river corridor using a GIS-based approach. Within each reach, we construct detailed Digital Terrain Models (DTMs) of the bed and bank topography by combining multibeam bathymetry of the channel with photogrammetrically derived contours and topographic data points collected from total stations. Bed texture mapping utilizes a combination of hill shaded multibeam topography, multibeam backscatter utilizing QTC Multiview, and underwater microscopy (Flying Eyeball). Sediment volumes and sand bar areas are calculated within each reach to better understand the spatial and temporal patterns of sediment storage between Glen, Marble, and Grand Canyons. We compare our observations with data on tributary sediment supply and mainstem sediment transport. Results from surveys in August and September 2000 during the Low Summer Steady Flows (LSSF), and in May 2002 will be presented. We focus on the techniques and associated errors associated with the different types of spatial data and the challenges of collecting and integrating large datasets.

The Relative Roles of Channel and Eddy Storage in the Colorado River in Marble Canyon: New Insights from Monitoring Individual Sites and Longer Reaches

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Abstract. A sand budget for the 99-km reach of the Colorado River in Marble Canyon was developed by incorporating measurements of sediment input and export from the reach, sediment grain-size distributions, and sediment volume changes at selected study sites. Sandbars and other sandy deposits in this reach were an integral part of the pre-dam riverscape, and are important for habitat, protecting archeological sites, and recreation. To determine the relative importance of eddy and channel environments for long-term storage of fine sediment (i.e., sand and finer material), two independent methods were used to determine the storage environment of the sediment eroded from Marble Canyon during two experimental high releases from Glen Canyon Dam: the 1996 controlled flood and the September 2000 powerplant capacity flow. The first of these methods relied on partitioning channel and eddy sediment by grain size; the second of these methods relied on direct measurements of topographic change at selected sites. There is a distinct difference between the grain-size distributions comprising the fine sediment stored in eddy and channel environments, with the grain-size distribution of the sand stored in eddies being far more similar to the grain-size distribution of the sand supplied by the Paria River (the principal post-dam supplier of sand to the Colorado River in Marble Canyon). Given the uncertainties in the methods, the budgets indicate that 54 to 95% of the sand in Marble Canyon is stored in lateral flow recirculation eddies, despite these areas comprising a small percentage (~17%) of the total river area. The total eddy sand storage prior to March 1996 was estimated to be 5.4 million Mg, an amount equivalent to about 3-4 times the mean annual sand supply from the Paria River. Eddy sand storage decreased by about 5% between March 1996 and August 2000. These results have important implications for managing the sediment supplied by the Paria River to this supply limited reach downstream from Glen Canyon Dam.

Sediment Mass Balance in Marble and Upper Grand Canyons Using Laser and Acoustic Technologies

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Abstract. Sandbars and other sandy deposits in and along the Colorado River in Grand Canyon National Park (GCNP) were an integral part of the pre-dam riverscape, and are important for habitat, protecting archeological sites, and recreation. These deposits have eroded substantially following the 1963 closure of Glen Canyon Dam that reduced the supply of sand at the upstream boundary of GCNP by about 94%; sandbars in the upstream portion of Grand Canyon have decreased in size by about 25% during only the last 15 years. Recent work has shown that sand transport in the post-dam river is supply limited, and is equally regulated by the discharge of water and short-term changes in the grain size of sand available for transport. During and following tributary floods, fine sand supplied to the Colorado River travels downstream as an elongating sediment wave. As the front of a sediment wave passes a given location, sand on the bed first fines and suspended-sand concentrations increase independently of the discharge of water. Subsequently, the bed is winnowed and suspended-sand concentrations decrease independently of discharge. By virtue of this process, sand supplied by tributaries is typically exported from the upstream portion of Grand Canyon within months under normal dam releases. Thus, newly input sand may be available to rebuild sandbars during controlled floods conducted only following large tributary floods. Accurate monitoring of sand transport in such a river requires frequent measurements of suspended-sediment concentration and grain size, and cannot be accomplished by using stable sediment-rating curves constructed from a sparser dataset of suspended-sediment measurements.

To monitor sediment transport in the Colorado River, we have designed and are evaluating a laser-acoustic system for measuring the concentration and grain size of suspended sediment every 15 minutes. This system consists of (1) a subaqueously deployed laser-diffraction instrument (either a LISST 100 or a LISST 25X) connected to an automatic pump sampler, and (2) an acoustic-doppler current meter. When laser transmission drops below a user-defined threshold (as a result of increased suspended-sediment concentrations), the LISST triggers the automatic pump sampler to collect samples at a user-defined rate. This allows samples to be collected when the suspended-sediment concentrations exceed the upper limit for the LISST and the acoustic-doppler current meter (around 2000-3000 mg/l). Beginning in August 2002, we began testing this system at 4 locations along the Colorado River in Marble and Grand Canyons, and have developed stable box coefficients relating the pump, laser-diffraction, and acoustic-backscatter measurements to cross-sectionally integrated measurements of suspended-sediment concentration and grain size. The locations of these 4 deployments are river-mile 30, river-mile 60, the Grand Canyon gage (at river-mile 87.4), and the above Diamond Creek gage (at river-mile 225.1). We chose these 4 locations to divide the Colorado River in Marble and Grand Canyons into four reaches for sediment budgeting: (1) upper Marble Canyon (from the mouth of the Paria River to river-mile 30), (2) lower Marble Canyon (from river-mile 30 to the mouth of

the Little Colorado River), (3) upper Grand Canyon (from the mouth of the Little Colorado River to the Grand Canyon gage), and (4) lower Grand Canyon (from the Grand Canyon gage to the above Diamond Creek gage). Data from these locations indicate that, given the uncertainties used in the sediment budget, no net change occurred in either the volume of sand or the volume of silt and clay in upper Marble Canyon, lower Marble Canyon, and upper Grand Canyon between August 2002 and June 2003. Sand supplied by tributaries accumulated in upper Marble Canyon and upper Grand Canyon during the period of lower dam releases from September through November 2002 (with peak discharges less than or equal to 10,000 ft^3/s each day). This accumulated sand was then eroded from these 2 reaches during the high-fluctuation experimental flows of January through March 2003 (with discharge ranging from 5,000 to 20,000 ft^3/s each day). Between August 2002 and June 2003, no periods of demonstrable accumulation or erosion of sand occurred in lower Marble Canyon.

Bed-sediment Grain Size and Influence on Sediment Transport

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Abstract. Recent studies of sediment transport in the Colorado River have shown that bed sediment becomes substantially finer when tributary floods introduce new sediment to the Colorado River during the monsoon season, and the bed becomes coarser when it is winnowed during intervening periods. The resulting changes in grain size of sediment on that riverbed are more important than changes in flow in regulating transport of sediment during normal dam operations. Such changes in grain size on the bed can cause the transport rate to change by 2-3 orders of magnitude for a given water discharge.

Two new approaches have been developed to address this problem of grain-size evolution on the bed; one is theoretical, and the other is observational and technological. The theoretical approach uses concentration and grain size of suspended sediment to calculate changes in grain size of bed sediment (Rubin and Topping, 2001). The technological approach uses an underwater digital microscope (U.S. Geological Survey, 2001) to directly measure changes in grain size on the bed.

Since this monitoring began several years ago, the grain size of sediment on the bed calculated from suspended sediment ("beta") has roughly mimicked the reach-wide sediment balance measured between the Paria River and the Grand Canyon gage (fining when sediment is supplied and coarsening during periods of winnowing). On a shorter time scale (days), changes in bed-sediment grain size reflect changes in stage (fining when the stage rises and the river has access to finer sediment along the channel margins).

Measurement of grain size observed in thousands of bed-sediment images documented grain-size changes during the 2000 "spike flow" experiment. The amount of coarsening and winnowing decreased systematically downriver. At five sites immediately downstream from the Paria River (river miles 1 to 3), mean grain size of surficial sediment coarsened most dramatically (from 0.17 mm to 0.58 mm). At four sites between river miles 29 and 45 mean grain size coarsened from 0.17 mm to 0.26 mm. Between river miles 60 and 65, three sites coarsened, and one site was unchanged. At two sites near river mile 68, mean grain size fined from 0.20 to 0.11 mm. All of these observed changes represent the preferential transport of fine sediment from upstream sites to downstream sites.

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Techniques in Multibeam Hydrographic Data Processing

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Abstract. Hydrographic technology is used in the Grand Canyon primarily to measure changes in the river channel. The primary changes that occur are due to the movement of sediment. These changes are monitored by hydro-acoustic measurements (depth sounder) that are accurately positioned systematically over the course of the river channel. Multibeam technology offers the best, most efficient way to collect hydrographic data. The two areas of multibeam surveying consist of an ongoing system-wide channel map and a repeatable reach monitoring for annual change detection. The data is processed and a Digital Terrain Model (DTM) is created. From the DTM volume comparisons of previous and subsequent surveys can be generated. Multibeam data does an excellent job of generating repeatable sub-aqueous topography for volumetric change detection. However, can multibeam data be used for repeatable bottom classification?

High resolution multibeam data, such as collected with the Reson 8125 for the FIST (Fine Grain Sediment Team) monitoring of the LTMS (Long Term Monitoring Sites), can be used to look at the sub-strait of the channel bottom. In most cases where hydro-acoustic backscatter data has been collected, there are a number of options available in the processing of this data that yield varying results for sub-strait analysis. There have been many recent developments in processing software that allow the user to process hydrographic data in many ways. Some of these software packages include: Coastal Oceanographic's Hypack, Caris Hips and Sips, Chesapeake Technology's Sonarweb, and Qwester Tangent's Multiview. This presentation will focus on the processing and editing of multibeam data, backscatter data, side-scan sonar and seabed classification.

Pre- and Post-Low Summer Steady Flows Side-scanning Sonar Imaging of the Colorado River, Grand Canyon

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Abstract. Immediately following the Low Summer Steady Flows (LSSF, 8000 cfs) and before the high 31,600 cfs flow of September of 2000, the USGS collected side-scanning sonar data along the Colorado River from Glen Canyon Dam to Diamond Creek (mile 224). Directly following that flow, a second data collection cruise was conducted along the same stretch. A study of the changes in the distribution of sand size sediment along the river was funded for the stretch between Glen Canyon Dam and Phantom Ranch (102 miles). The side-scanning sonar imaging focused on the pools between rapids and imaged smaller rapids when possible. Patterns of sediment distribution showed that sand size sediment occurred both before a rapid in the form of sand waves and mega ripples and downstream from the rapids in the form of reattachment bars. Sediment distribution within the pools was a function of water depth, width of the channel, morphology of the channel, and distance downstream of a constriction in the river. The movement of sediment downstream appeared to fluctuate with location in the channel. Because side-scanning sonar can only give areal distribution of sand size material it was not possible to give volumetric changes in the movement of sand. What the data do provide is an indication of sediment coarsening and fining, and deposition and erosion between surveys. All data collected is archived at the offices of the Coastal and Marine Geology Team of the U.S. Geological Survey.

Geomorphic Change Detection in Grand Canyon: Comparison of 2000 LIDAR and 1923 Survey Data

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Abstract. Debris flows in Grand Canyon constrict the Colorado River, increase the water-surface fall through rapids, and raise the elevation in the upper pool, potentially decreasing the fall in upstream rapids. Long-term monitoring of changes created by debris-fan reworking help assess the stability of pool-rapid controls of the river's hydraulics. In 1923, Col. Claude Birdseye led a U.S. Geological Survey team in measuring the longitudinal water-surface profile through Grand Canyon using simple theodolite and stadia survey techniques. In 2000, a LIght Detection And Ranging (LIDAR) over-flight collected topographic data centered on the river corridor and water surface, representing the first comprehensive measurement of water-surface profile since 1923. Though absolute topographic accuracy of the Birdseye Survey is poor by today's standard, comparison of the two water-surface profiles is possible. Using unchanged rapids as "anchors" (i.e., those rapids not historically effected by debris flows and identified with repeat photography), the Birdseye data were tied to the LIDAR data at specific points along the river. The Birdseye data between anchors were then adjusted horizontally and vertically, aligning the two data sets and allowing direct comparison. By juxtaposing the Birdseye and LIDAR profiles, the effect of 77 years of Grand Canyon debris-flow activity and river reworking on the river water surface was quantified. Comparison of the 1923 and 2000 data can identify rapids with elevated water surfaces, thus marking those tributaries that produced historical debris flows. In addition to measuring change over 77 years, the creation of a new water-surface profile, more detailed than the Birdseye survey, allows generation of a new and updated set of geomorphic statistics for Grand Canyon.

Data Management at the Grand Canyon Monitoring and Research Center

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Abstract. Data management at the Grand Canyon Monitoring and Research Center consists of three core information technologies and a set of data standards that specifies delivery requirements. Data management emphasizes data reliability and consistency while providing data consolidation, organization, longevity, availability, integration, and security. Core information technologies utilized are a database management system, a geographic information system, and a library for tabular, spatial, and hardcopy data, respectively. This data management strategy is heavily dependent on computer and software infrastructure and digital data, provides the greatest degree of automation, and preserves data integrity over time.

GCMRC Library Scanning Project

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Abstract. The Grand Canyon Monitoring and Research Center (GCMRC) measures the effects of Glen Canyon Dam operations on the resources along the Colorado River from Glen Canyon Dam to Lake Mead. The GCMRC library supports GCMRC scientists and investigators, Adaptive Management Work Group (AMWG) and Technical Work Group (TWG) members, and public interests in the Colorado River ecosystem by providing an infrastructure for organizing, archiving, and disseminating information such as reports, maps, aerial imagery, slides, and videos.

The GCMRC is in the process of converting its collection of rare and one-of-a-kind materials to digital format. This project will serve to preserve the original media as well as allow for more effective distribution of data over great distances. Once the hardcopy media is scanned, the digital information will be stored in file formats suitable for distribution via the Internet and can be analyzed using computer software.

File formats were selected to ensure that they meet the following criteria:

- non-proprietary
- industry standard
- preserves the integrity of the information contained on hardcopy media
- loss-less compression

This project is scheduled for completion in 2008 at which time all library contents not restricted by copyright law will be available electronically.

Grand Canyon Integrated Database Management System

Cory Lochridge[1], Christopher Flaccus[2], Steven Mietz[2], James Slebodnick[3], Robert Daugherty[3], David Brink[3]

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Abstract. The Grand Canyon Monitoring and Research Center (GCMRC) was founded to study the effects of the operation of Glen Canyon Dam on downstream resources within the Colorado River ecosystem. The mission of the database development project at GCMRC is to create an accessible, multi-disciplinary, spatially referenced database to consolidate, organize, document, store, and distribute the results of these studies. For the past year-and-a- half, the GCMRC has been working cooperatively with the Center for Data Insight at Northern Arizona University in developing such a system using the Oracle relational database management software. A key challenge has been to bring together disparate sources of data and information, collected over the past twenty or more years, into a common spatial and temporal scheme that can be used for ecological analysis and ultimately decision support. The following presentation will highlight some of the steps followed in this development project, the major components of the system, and give a demonstration of some of its capabilities.

Building an Integrated Ecological Spatial Database for the Grand Canyon using Spatial Database Engine, Internet Map Server, and Oracle Database Management System

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Abstract. The Grand Canyon Monitoring and Research Center (GCMRC) measures the effects from Glen Canyon Dam operations on the status and trends of resources along the Colorado River from Glen Canyon Dam to Lake Mead. The goals of the GCMRC are to develop monitoring and research programs as well as related scientific activities that evaluate short- and long-term impacts of the Glen Canyon Dam on the biological, cultural, and physical resources of the Colorado River Ecosystem (CRE). An integrated ecological spatial database was required for the archiving, organizing, distribution and analysis of spatial and tabular data collected within the CRE. The consolidation of disparate datasets from numerous sources provided a unique challenge. To address this challenge, spatial and temporal keys were used to organize the data in a single, comprehensive database using ESRI's Spatial Database Engine (SDE) and Oracle Database Management System. The flexible database structure offered by SDE and Oracle allowed the use of a variety of query and analysis tools including Internet Map Server (IMS), Structured Query Language, web-based forms, Open Database Connectivity and Geographic Information Systems client connections. This presentation focuses upon the use of the Internet Map Server application as a query and analysis tool for spatial and tabular datasets including a live demonstration of many of the capabilities of the IMS.

Establishing a Control Point Database

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Abstract. The Grand Canyon Monitoring and Research Center (GCMRC) Survey Department is charged with establishing a reference frame for the spatial positioning of scientific data collected in the Colorado River Ecosystem (CRE). Using GPS technology combined with conventional survey methods, control points are geo-referenced to the Arizona Central State Plane grid. The control point database is a compilation of contemporary GCMRC control points and documented historical GCES control points. The contemporary control points include GPS points as well as conventionally surveyed points with coordinate values in the NAVD88 vertical reference system and NAD83 horizontal reference system in the Arizona Central State Plane grid (in meters). The historical GCES control points were originally documented in NAD83 horizontal reference system and NGVD29 orthometric vertical datum and subsequently converted to NAVD88 vertical reference system by GCMRC; the conversion produced up to 1 meter error rendering the coordinate values useless in change detection applications. Recently, the historic GCES control points were re-adjusted using contemporary GPS control point coordinate values generating coordinate values referenced to NAVD88/NAD83 datum. The results are preliminary and will be verified before inclusion into the database.

The control point database also uses a standard naming convention based on river mile and documents metadata associated with the physical point as well as the metadata for the coordinate value i.e. photographs, site descriptions, projects associated with point, point name alias, coordinate datum, method of deriving coordinate, and errors associated with the coordinate value, etc.

Not only is the control point database useful for providing information about a point, but combining the database information with a GIS can also prove to be a useful tool for planning geo-referenced data collection operations. Identifying control points to use in a research area eliminates the need to set a new point, or unknowingly set a point within meters of an established point. Ultimately, access to the control point database will be available through the Internet, and ideally, control points used and documented by contractors and cooperators will also be integrated into the database.

Synthesis of Results and Application to River Management

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Abstract. On-going monitoring of sediment transport, channel and eddy topography, and bed material has clarified our understanding of the Colorado River in Grand Canyon as a sediment depleted stream whose major reservoirs of fine sediment are in eddies. The resulting eddy bars are thus a significant component of the sediment mass balance of the physical system and a significant physical component of the riverine ecosystem. Advances in scientific understanding highlight the imperative that Glen Canyon Dam be managed and operated adaptively, because new scientific insights have management implications. In the case of the Integrated Fine-Sediment Monitoring Program (FIST) and related projects concerning measurement of canyon-wide sediment mass balance and prediction of future physical conditions using numerical models, these implications affect (1) the establishment of management objectives for rehabilitation of the ecosystem, (2) flow manipulation techniques, including the role of dam releases that exceed power plant capacity, (3) fine sediment management techniques, and (4) monitoring strategies. Physical scientists have also come to realize both the longitudinal gradients and inherent site-scale variability in fine sediment storage that suggest the development of segment-average segment-specific objectives for fine-sediment resources. In this talk, we will review the major recent scientific findings related to fine-sediment transport and storage and describe management implications of these findings.

Effects of a Low Summer Steady Flow Experiment on Native Fishes of the Colorado River in Grand Canyon, Arizona

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Abstract. A Low Summer Steady Flow (LSSF) experiment was conducted in 2000 with releases from Glen Canyon Dam down the Colorado River through Marble Canyon and Grand Canyon. One purpose of the LSSF was to determine if low steady flows in summer would stabilize habitat and allow the Colorado River to warm sufficiently for increased growth and survival of the endangered humpback chub (*Gila cypha*) and other native fishes. Data on species composition, relative abundance and distribution of fishes were gathered using a variety of gear types during and after the LSSF to provide a baseline for long-term monitoring and an evaluation of short-term response to the experimental flows.
Mean mainstem temperatures were 1.4-3.0°C warmer than under previous dam operations (Modified Low Fluctuating Flows [MLFF]), and mean backwater temperatures were 0.3-5.3°C warmer; hence, a marked warming effect was observed. Longitudinal downstream warming greater than that during MLFF was observed. Growth patterns of YOY flannelmouth sucker and bluehead sucker were inconclusive during the LSSF because protracted spawning infused newly-hatched larvae into samples and kept average YOY lengths depressed. Growth patterns of YOY HBC were not significantly different from MLFF growth patterns. Catch-Per-Effort (CPE) of YOY HBC was not significantly different than during MLFF. CPE of bluehead sucker, and flannelmouth sucker was significantly higher ($\alpha = 0.05$) in August 2000 than in July/August from 1991-1997. Nonnative fathead minnow CPE was much higher than previous levels but the differences were not significant due to greater variation in CPE. Following the September flow spike, CPE of all species declined. However, fathead minnow CPE was nearly identical with previous years while CPE of native fishes remained significantly higher ($\alpha=0.05$), suggesting the flow spike was disproportionately detrimental to the nonnative fathead minnow.

Responses of Native and Non-Native Species to Two Managed Flow Regimes Below Glen Canyon Dam, Grand Canyon, Arizona

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Abstract. We examined patterns of establishment and survival of clonal, native herbaceous species and the exotic shrub, tamarisk along the Colorado River in Grand Canyon, Arizona, to two flow regimes: a summer-long low, steady flow with high "spike" flows before and after (year 2000) and low fluctuating flows (year 2001). Based on life history differences, we hypothesized that all plant species would colonize newly exposed beaches during low steady flows, but fluctuating flows would have a greater negative impact on tamarisk than on native plants. Six major patterns were found: 1) tamarisk seedlings established in the newly exposed areas rapidly and in large numbers during low steady flows; 2) native species colonization occurred from established high elevation plants down toward the water and increased throughout the duration of these two flows; 3) 2e observed a decrease of approximately 60% in tamarisk seedlings but not in the dominant native plant following a 4-d spike flow at power plant capacity at the end of the low flows of 2000; 4) during the following growing season, low fluctuating flows produced a switch in dominance from tamarisk to native vegetation; 5) seed-dispersed tamarisk established primarily in the middle of the newly exposed habitat whereas native clonal species colonized from established populations in the higher elevation areas; 6) reduced water levels during low flows caused a die-off of stems of native clonal species in high elevation areas, but these losses were offset by establishment closer to the waterline. We duplicated the observed patterns of horsetail mortality with a rhizopod experiment in the greenhouse, and found that mortality is greatest when root crowns are more than 70cm above the water table, in agreement with patterns seen in the field. These results argue that in the terrestrial riparian community now found in Grand Canyon, a low steady flow regime in Grand Canyon favors tamarisk establishment while low fluctuating flows favor increased densities of native plants. We also suggest the need to manage regulated river ecosystems with multiple-year plans rather than shorter time spans often utilized in more conventional management plans.

Modeling Effects of Discharge on Habitat Quality and Dispersal of Juvenile Humpback Chub (*Gila cypha*) in the Colorado River, Grand Canyon

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Abstract. A two-dimensional hydrodynamic model was applied to seven study reaches in the Colorado River within Grand Canyon to examine how the operation of Glen Canyon Dam has effected the availability of suitable shoreline habitat and the dispersal of juvenile humpback chub (*Gila cypha*). Suitable shoreline habitat typically declined with increasing discharges above 226-425 cubic meters per second, although the response varied among modeled reaches and was strongly dependent on local morphology. The area of suitable shoreline habitat over cover types that are preferred by juvenile humpback chub, however, stayed constant, and in some reaches, actually increased with discharge. In general, changes in discharge caused by impoundment tended to decrease the availability of suitable shoreline habitat from September to February, but increased habitat availability in the spring (May-June). Hourly variation in discharge from Glen Canyon Dam resulting from power load following substantially reduced the amount of persistent shoreline habitat at all reaches. Changes in suitable shoreline habitat with discharge were shown to potentially bias historical Catch Per Unit Effort indices of native fish abundance up to fourfold. The physical retention of randomly placed particles simulating the movement of juvenile humpback chub in the study reaches tended to decline with increasing discharge, but the pattern varied considerably due to differences in the local morphology among reaches and the type of swimming behavior that was modeled. The implications of these results to current hypotheses about the effects of Glen Canyon Dam on juvenile humpback chub survival in the mainstem Colorado River are discussed.

Longitudinal and Near-shore Warming Patterns of the Colorado River During LSSF Experiment

William S. Vernieu, U.S. Geological Survey-BRD, Flagstaff, AZ

Abstract. The GCMRC thermal monitoring program measures longitudinal warming of the Colorado River in Grand Canyon and collected data during the Low Summer Steady Flows (LSSF) experiment in 2000. Water temperature of Glen Canyon Dam releases ranges from 7°C to 12°C with warmest water released in late December followed by coolest water in March. Maximum downstream warming occurs during the month of June and varies with discharge level. The Colorado River at Diamond Creek experienced 10°C warming above tailwater temperatures at discharge levels of 8000 cfs in June 2000 compared to less than 5°C warming during high steady discharge of 26,000 cfs in June 1997. Significant warming of near-shore environments occurred during the LSSF in shallow water with little or no velocity. Warming of these environments appears to be mainly a function of direct solar ensolation and the degree of isolation from the main channel. Temperatures of up to 18.5°C (7°C above river temperature) were observed in open near-shore areas. Temperatures of up to 29°C (12°C above river temperature) were observed in backwaters. Small or larval fish were observed at all study sites.

Downstream Water Quality Effects of Drops in Lake Powell Elevation, 2003

Susan Hueftle, U.S. Geological Survey-BRD, Flagstaff, AZ

Abstract. Drought conditions have lowered Lake Powell elevations to nearly 100 feet below full pool elevation by the end of summer, 2003. As a result, Glen Canyon Dam's penstock intakes are closer to the lake's surface than they have been since 1973, resulting in some of the highest summer discharge river temperatures seen since that time, approaching 12 °C (53.7 °F) by end of August. As the reservoir filled in the 1960's and 70's, release water quality migrated from seasonal river patterns to a reservoir pattern where discharge temperatures peaked during the late fall- winter of mixing followed by coldest releases in February and March. Lowered lake elevations have produced discharge temperatures over 2°C (4-5 °F) above decadal norms. Temperature alone is not affected by epilimnetic withdrawals from Lake Powell. Conductivity discharge patterns are also reflective of epilimnetic releases, which reflect the suite of chemical ions that contribute to conductivity. While releases begin to resemble the reservoir's epilimnion, the epilimnion itself is transformed by the conditions of the drought and drawdown. Hypoxia could be passed downstream as current oxygen levels drop in the reservoir.

The changing discharge water quality may influence numerous aspects of downstream ecology. Additionally, projections for extended drought could further lower the lake and result in greater deviations from typical releases of the past 15 to 20 years. Here we provide an explanation of the processes that produce these effects, examine past instances of warm summer releases, and look into the future.

Implications of Low Summer Steady Flows on Whitewater Boating Safety and other Recreational Attributes

Linda Jalbert, National Park Service, Grand Canyon, AZ

Abstract. Based on previous research, management prescribed flows from Glen Canyon Dam have been found to influence river trip experiences through Grand Canyon. Attributes include rate of travel, "whitewater thrill", the size and perceived safety of rapids, time spent off-river at attraction sites and camps, and the quality of camps and beaches.

In 2000, three recreational studies looked at the effects of the 8,000 cfs, Low Summer Steady Flows (LSSF). One study examined behavioral changes in recreational rafting trips by comparing river trip "diary" data from 1998 and 1999 (considered to represent a "typical" flow regime), and from 2000 (low flow regime). These data illustrated differences in the amount travel time, time spent at campsites and attraction sites, and how campsite selection changed. Another study examined the economic impacts of the LSSF to whitewater boaters. Data reported by commercial river outfitters showed that economic impacts during the LSSF differed significantly than under normal operations. These economic impacts are related to the findings of a third study that examined the effects of the LSSF on whitewater boating safety.

This study was a continuation of recreational boating safety studies conducted as early as 1985, and again during the higher "flood" flows in Spring 1996. Documentation of observed incidents at "major" rapids, and investigation of NPS case files was compared at low, medium and high flow regimes. Analysis of observed data supports previous findings that accident variables such as hitting rocks and equipment damage are related to low flows of 5,000 to 8,000 cfs. Compared to the previous year, the NPS case incident data showed a 100% increase in the number of reported incidents. In summer 2000, the NPS responded to nine boat-grounding incidents. Five of these incidents required removal of passengers from large motorized rafts using short-haul rescue operations. For many of the recreationists, a long-awaited Grand Canyon river adventure was unexpectedly and prematurely terminated.

Phyto-Benthic Response to the 2000 and 2003 Ecological Restoration Flows in the Colorado River Below Glen Canyon Dam

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Abstract. Two experimental flows were released from Glen Canyon Dam within a three-year period with two very different hydrographs. However, both were attempting to meet the two prime management objectives: recover native fish and conserve sand. In 2000 spring high flows, with a spike flow of 835 m^3/s, were followed by three months of steady 227 m^3/s flows and another spike flow in September. Between January and March 2003 flows fluctuated between 142 and 567 m^3/s in an effort to "disadvantage" alien fish thought to be competing with native fish. We collected water quality data, estimated the mass of organic drift, phytobenthos, and monitored near shore vegetation. During both collection periods water quality varied from past data because of flow in 2000 and changes in the elevation of Lake Powell in 2003. High winter and spring flows reduced benthic biomass while increasing organic drift in the short-term. New Zealand Mudsnails were the dominant macroinvertebrates during both periods, while Cladophora remains < 5% of the biomass having been replaced by a variety of highly tolerant algal taxa. Chironomid biomass has remained consistent while Gammarus biomass has dropped during the past three years. We recommend that experimental flow regimes be simple in design and extend for at least three years so natural variation from tributaries and recent water quality changes within Lake Powell can be assessed.

Economic and Financial Effects to Electrical Power Production from Experimentation at Glen Canyon Dam: LSSF and Proposed Sediment Retention Flows and Non-Native Fish Removal Flows

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Abstract. The Grand Canyon Protection Act of 1992 requires the Secretary of the Interior to mitigate adverse impacts to the Grand Canyon National Park and Glen Canyon National Recreation Area. The U.S. Department of the Interior, in order to mitigate adverse impacts, has implemented experimental releases from Glen Canyon Dam.

The initial implementation of experimental releases from Glen Canyon Dam during 2002 was outlined in a document issued December 31, 2000, entitled: A Program of Experimental Flows for Endangered and Native Fishes of the Colorado River. The 2002 experimental releases are referred to as the Low Summer Steady Flow (LSSF) releases. The operation of Glen Canyon Dam was altered from March 1, 2000 to September 30, 2000. The purpose of the LSSF was to remove the risk of further jeopardizing two endangered species below Glen Canyon Dam—the humpback chub and razorback sucker. This change in operation also modified the production and timing of electrical generation at the Glen Canyon Dam power plant.

In September 2002, the U.S. Department of the Interior issued an Environmental Assessment (EA) that outlined further experimental releases from Glen Canyon Dam. The experimental releases proposed in the EA are referred to as the Proposed Action. The first year of the Proposed Action has been completed, and additional experimentation outlined in the EA is currently being conducted.

The Proposed Action altered the operation of Glen Canyon Dam beginning September 2002. This change in operations was intended to provide flows to aid in the decrease of sediment transport below Marble Canyon and aid in the recovery of the humpback chub by removing non-native fish and improving habitat for young native fish. This change in operation also modified the production and timing of electrical generation at the Glen Canyon Dam power plant.

This paper describes Western Area Power Administration's method for simulating the operation of Glen Canyon Dam power plant in tandem with the other Colorado River hydroelectric power plants for the LSSF and the Proposed Action. It also examines Western Area Power Administration's methods for estimating the financial and economic cost of these changes in operations and calculates the gain and loss of power revenues.

Brown Trout Removal in Bright Angel Creek, Grand Canyon National Park: A Potential Recovery Effort for Native Fishes

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Abstract**.** In Bright Angel Creek in Grand Canyon National Park, the fish community has been altered towards non-native salmonids, to the detriment of its native fishes. The National Park Service is charged with preserving and protecting the natural resources within Grand Canyon. Active, hands-on management of resources is at times required to achieve this goal. Construction and operation of a temporary weir in Bright Angel Creek will provide the opportunity to determine if removal of brown trout (*Salmo trutta*) will benefit native fish survival in Bright Angel Creek. In the mainstem Colorado River, maximum brown trout numbers occurred near the confluence of Bright Angel Creek. Bright Angel Creek is thought to be the primary spawning location for brown trout in the Grand Canyon, although mainstem spawning may also occur. Removal of spawning brown trout from Bright Angel Creek may reduce the numbers of brown trout in the mainstem as well, thus potentially benefiting the endangered humpback chub and other native fish in the mainstem. A temporary fish weir was installed in Bright Angel Creek and operated continuously from November 18, 2002, to January 21, 2003. Spawning brown trout were collected in the weir and removed from the creek. Removal of brown trout and annual monitoring to document the fish community response will be conducted for four years.

Mechanical Removal of Non-Native Fishes in the Colorado River within Grand Canyon: An Update on 2003 Operations and Results

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Abstract. In response to declining trends in both sediment resources and native fish stocks, the Glen Canyon Dam Adaptive Management Program recommended to the Secretary of Interior that a set of experimental treatments be conducted to better understand mechanisms to conserve sediment and factors contributing to native fish recruitment dynamics. As part of this experiment, non-native fishes were removed from humpback chub habitat near the confluence of the Little Colorado River. This effort focuses primarily on three objectives:
(1) evaluating the relationship between non-native abundance and humpback chub population dynamics; (2) efficacy of non-native fish mechanical removal in a distinct segment of the Colorado River; and (3) diet and predatory habits of non-native fishes in the Colorado River. During six trips conducted in winter and summer of 2003, a total of 11,970 non-native fishes were removed from the primary and secondary removal reaches (River Mile 56.2 – 72.7). The majority of the removed fish were rainbow trout (95%, 11,399 fish) with brown trout (2%, 241 fish) and common carp (2%, 236 fish) contributing the majority of the remainder. Depletion abundance estimates indicated 5-pass removal efficiencies ranged between 55% and 65% for rainbow trout and between 67% and 85% for common carp. Removal efficiencies for brown trout exhibited higher variability ranging between 26% and 65%. Rainbow trout immigration to the removal reach from proximal areas of the river was estimated to be approximately 38 fish/day under a depleted condition. Relative abundance of humpback chub juveniles as indexed using hoopnet catch rate increased through the course of 2003. This atypical pattern may indicate increased survival or near-shore habitat utilization as a result of lower non-native fish density.

Spatial and Temporal Patterns in Rainbow Trout Redds and Fry in the Lees Ferry Reach of the Colorado River: Implications for Fluctuating Flows from Glen Canyon Dam

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Abstract. Increased fluctuations in flows (5-20 kcfs) from Glen Canyon Dam were implemented in Jan-Mar, 2003 as a means of reducing the survival of early life stages of rainbow trout. We surveyed redd locations and fry populations on a monthly basis in the Lees Ferry reach from Jan-Oct, 2003 to assess the potential impacts of the increased flow fluctuations. Relationships between depth, velocity, and substrate and spawning habitat suitability were also evaluated as a means of predicting spawning elevations under different discharges in the Lees Ferry reach.

In 2003, the majority of spawning occurred between Feb. and May. The total count across 4 intensively monitored sites (Four Mile Bar, Ferry Swale, Powerline and Pumphouse bars) exceed 500 redds during the peak in Apr. The proportion of redds at elevations <=5, 5-8, 8-12, 12-15, and 15-20 kcfs was 0.34, 0.16, 0.17, 0.21 and 0.12, respectively. Redds at elevations >12.5 kcfs were completely dewatered after Apr 1 (ca. 33% of redds). Lethal intra-gravel temperatures as low as the 10 kcfs stage occurred at Four Mile bar (11 miles downstream of dam) by Mar. and by Apr. at Powerline Bar(1 mile downstream of dam). Considerable losses in the egg deposition at the 8-12 kcfs stage likely occurred at Four Mile Bar due to temperature-induced mortality. A system-wide survey of redds over the Lees Ferry reach (excluding intensive sites) showed a higher proportion of redds at lower elevations (<5 kcfs: 0.43, 5-8 kcfs: 0.37, 8-20 kcfs: 0.20) relative to intensive sites. The peak count of 427 redds from the system-wide survey occurred in Apr. Based on the timing redd construction and their elevations, we estimated that about 30% of the egg deposition in the Lees Ferry reach was lost due to dewatering effects in 2003.

Spawning tended to occur over pea- to fist-sized gravel substrates at depths and velocities less than 1.5 m and 1 m/sec, respectively. Higher discharges during winter months (up to 20 kcfs) likely increased the elevations at which spawning occurred, and therefore increased the mortality of eggs and alevins due to dewatering and temperature effects when discharges were decreased on Apr. 1.

Monthly catch-per-effort fry sampling by backpack electrofishing at index sites showed peak abundance of very small fish (25-30 mm) in Jun. with few fry of any size observed before May. A large subsample of captured fry were aged by counting daily growth rings present on the otolith. The length-age relationship combined with length-frequency analysis suggests that peak emergence occurred in May. The timing of 2003 fluctuating flow experiment was too early to affect small fry in the Lees Ferry reach, however the large decrease in fry densities between late Jul. and early Sep. sample periods suggests the change in minimum flows from 12 kcfs to 5 kcfs in early Sep. 2003 may have had a significant impact. The utility of using combined length-frequency analysis and direct ageing for estimating the annual fry survival rate is discussed.

High-resolution Photogrammetry and the Gully Erosion of Cultural Sites

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Abstract. Gully erosion has been damaging cultural sites in Grand Canyon over the last several decades, and there is a need to protect these features through monitoring, mitigating, and continuing to improve our understanding of the erosion. We performed total-station surveys, obtained detailed aerial photographs, and collected several types of geomorphic field data before and after the summer 2002 monsoon season at nine different sites with a total of 22 gullies and 113 erosion-control structures.

Aerial photogrammetry was performed on a subset of four sites in western Grand Canyon with 1:1600 scale photographs in order to assess the accuracy and utility of this remote sensing tool for monitoring gully erosion. Mean vertical error for individual datasets ranged from 6-10 cm, depending upon the degree of data interpolation. Considering the compounded errors associated with successive monitoring, accuracy was inadequate to identify most decemeter-scale erosion features. Sources of error include obstruction by vegetative canopy or shadows, and error also increases with topographic ruggedness and decreases with greater density of photogrammetric data. Considering this, we calculate the distribution of photogrammetric data that would minimize error at sites, which could reduce mean error to ~5 cm for individual datasets at this photographic scale in the future. Though photogrammetry is not yet suitable for monitoring sites with moderate erosion, it likely will be with technological advances and should be pursued in the future.

Repeat ground surveys show that gully erosion is concentrated at knickpoints and that new knickpoints tend to form in relatively steep reaches. Initial field data suggest soil shear strength and infiltration capacity vary significantly with sediment texture, vegetation, and soil crusts. An empirical slope-area erosion threshold for study gullies was applied in a preliminary model to identify locations hypothetically sensitive to gully erosion. Future numerical modeling that includes parameters from field geomorphic data has very high potential for use in cultural site management and monitoring, as well as for identifying the causes of the erosion.

Modeling of Sand Deposition in Archeologically Significant Reaches of the Colorado River in Grand Canyon

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Abstract. The development of gullies adjacent to the Colorado River in Grand Canyon has led to the exposure and destruction of archeological artifacts. Hereford and others (1991, 1993) proposed that the initiation and propagation of these gullies are related to the effects of Glen Canyon Dam on river stages and the main-stem sand supply. They also suggested that restoration of sand deposits at river level could lead to stabilization of the gullies and relieve or reduce future damage to the archeological artifacts. Wiele and Torizzo (in press) speculated that the development of gullies in the post-dam era may be related to the erosion of riverside sand bars that had been sources for wind-distributed sand. This study examines the response of sand deposits in four reaches mapped by Hereford and others (1991, 1993) to variations in dam releases and sand supply. Deposition rates and volumes resulting from two discharges and three sand conditions were computed using a model of flow, sand transport, and bed evolution (Wiele and others, 1996, 1999). The results for reaches dominated by recirculation zones show trends similar to those from previous studies of reaches with similar morphology, but show a greater variability of responses in reaches in which recirculation zones are minor. In addition to sand supply, the deposit volume and deposition rate is generally sensitive to the water discharge: higher discharges generate higher stages and larger deposition accommodation spaces with larger deposits as a result. Most cases show rapid initial responses in which the channel deposits reach a near-equilibrium within 1-2 days. Future dam releases designed to rebuild sand bars efficiently would likely yield the best results with high water discharges and high sand supplies. Ideally, these would be associated with recent significant tributary flows, but the duration need not be as long as the 7-day high flow released in 1996. Recirculation zones tend to accumulate sand during high flows at rates and volumes proportional to sand supply and water discharge; other reaches with seemingly simpler geometry, however, may show more varied responses.

The Role of Eolian Sediment Transport in the Preservation of Archeological Features: A New Research Initiative in Grand Canyon National Park

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Abstract. Eolian (wind-blown) sedimentation is a major process that affects sand transport, sand storage, and geomorphic evolution of the Colorado River corridor in Grand Canyon. Trapping of sediment behind Glen Canyon Dam has led to smaller sand bars along the river, reducing the source area for sand that can be transported by wind to higher elevations. The elimination of natural floods prevents sand from being deposited at pre-dam flood elevations, further reducing the sediment available for eolian transport. Absence of floods has also allowed vegetation to encroach upon eolian areas and river-level bars; dense vegetation reduces the ability of wind to rework and transport sediment in such areas.

Many archeological sites located near the river level were built in and on eolian deposits, above the pre-dam annual flood level. The reduction of sand available for eolian transport is believed to be a major factor contributing to observed high rates of erosion of archeological features along the river corridor; many cultural features that had been buried in eolian sand are exposed as wind deflates the land surface on which they are built, while bringing in little to no new sediment. This new research initiative, a cooperative study between USGS sedimentologists and National Park Service archeologists, sponsored by GCMRC, will evaluate the importance of eolian sedimentation at archeological sites along the river, and will assess the conditions and management strategy necessary to maximize their preservation.

Adopt A Beach Project:
Long Term Monitoring of High Demand
Camping Beaches in Grand Canyon

Kate Thompson, Grand Canyon River Guides, Inc., Dolores, CO

Abstract. The Adopt-a-Beach (AAB) program has completed its seventh year as a study that monitors annual camping beaches in Grand Canyon. This program, sponsored by Grand Canyon River Guides, Inc., is implemented by a 100% volunteer force of river guides, scientists, and NPS personnel. Results are submitted to various agencies such as the Cultural Resources Program of the Grand Canyon Monitoring and Research Center (GCMRC). Results are also presented to the Adaptive Management Program so that private and commercial recreational interests are represented as stakeholders in Colorado River management as reported to the Secretary of the Interior.

Adopt-a-Beach is a program of repeat photography that documents the changing conditions of a selected set of Grand Canyon camping beaches from April through October of each year. The selected beaches lie within five critical reaches of the river corridor. A critical reach is defined as an extended area in which camping beaches are sparse, small, and/or in high demand. The program assesses visible areal change to beaches resulting from changing regulated-flow regimes, rainfall, wind, and human impacts. Volunteers for this program are unique in that they run the Colorado River many times in one season, and they are able to provide sets of repeat photographs for each study beach. To date, guides have produced over 1,000 repeat photographs and associated field sheets having recorded the sequential condition of beaches throughout the commercial boating season, year after year. Research results include: (1) total cumulative change to beaches after a summer season and the processes that affect change, (2) change to beaches after a winter season, (3) longevity of the 1996 beach/habitat building flow (BHBF) deposits, (4) change in campsite quality throughout the summer season, and (5) areal change to beaches following any experimental flow.

The most recent high flow experiment of 30,000 cfs was conducted during fall of 2000. To date, this deposit is either very narrow and thin, or no longer exists on campsite beaches. The primary cause of erosion, reported by guides for river season 2002, was the moderately high fluctuating flows of 10,000-18,000 cfs throughout July and August.

The most significant event recorded by guides was the small beach-building event caused by the Little Colorado River (LCR) flood in early September 2002. Morphological changes resulted in new low-elevation benches (around the 20,000 cfs zone) and sand bars that covered pre-existing gravel-and-boulder bars. The combined mainstem with LCR flood peaked at about 22,000 cfs. The resulting beachfront deposits suggest that a coordinated mainstem spike with an LCR flood can be very effective in building beaches or low-elevation bars.

The longevity of the BHBF deposit since 1996 shows varying results. As of fall 1999, 59% of camps had returned to their pre-BHBF condition (O'Brien and others, 2000). Results of the 2000 HMF flows showed that 78% of beaches were again larger than their pre-BHBF condition, within the 20,000 to 30,000 cfs zone. Then by September 2001, 45% of the adopted beaches had returned to conditions similar to that before the BHBF. Campsite areas within the 30,000 and 45,000 cfs zone have continued to decrease overall throughout the years. At least 30% of beaches have apparently developed quasi-stable deposits within this zone, as they show no to very little change.

The Low Steady Summer Flows (LSSF) of year 2000 provided more diverse camping, both upstream and downstream of campsites within the study set, and within the campsite itself, according to guide response for 31 beaches. The combination of the HMF followed by the LSSF proved beneficial to 78% of all studied beaches.

These results contrast with those of the 1999 river season, during which a high percentage of beaches lost area due to flash floods, and a small percentage were affected by fluctuating flows. Before 1999, beaches had been eroding at a decreasing rate, mostly from fluctuating flows, as reported by guides and supported by visual cutbank retreat in photographs (O'Brien and others, 2000). Typically, rapid adjustment of newly aggraded beaches to fluctuating flows following a high release leads to initial high rates of erosion. These rates then fall off over time (Hazel and others, 2001). According to many guide remarks, campsite beaches were "primed and ready" for the HMF and LSSF regime of 2000. Then by September 2001, guides reported that camping had become harder on about 50% of the beaches. This loss of campsite quality directly relates to beach erosion. Other reported influences include tamarisk encroachment.

These results suggest that any newly deposited sand will be quickly eroded if subsequent high fluctuating flows are released from Glen Canyon Dam. This was evidenced by 3 events: (1) High steady flows (of about 27,000 cfs) following the 1996 BHBF eroded much of the new deposit at all beach sites through the summer of 1996 and 1997; (2) High fluctuating flows following the fall HMF of 1997 stripped away the new deposit entirely by spring 1998; and (3) Medium fluctuating flows following the fall HMF of 2000 eroded most of the new deposit by spring 2001. To date, at least 30% of beaches still show evidence of high-elevation sand (above 30,000 cfs line) deposited by the 1996 BHBF. However, the amount of sand appears to be diminishing from year to year. Annual implementation of HMFs in spring and in fall would help preserve this deposit by maintaining the beachfront. A regimen of Beach Habitat Building Flows followed by low fluctuating flows is needed periodically to rebuild campsite areas above the 30,000 cfs line. However, future BHBFs need to have enough sediment in the system so as to preserve Marble Canyon beaches and lessen impacts on lower beach areas (below the 20,000 cfs line) system-wide.

Towards an Understanding of Social Impediments to Adaptive Management in Grand Canyon

Christopher Updike, Northern Arizona University, Flagstaff, AZ

Abstract. The Colorado River reach within Grand Canyon is a close-coupled complex socio-ecological system. The construction of large-scale water management projects and the introduction of non-native sportfish have resulted in a socially undesirable domain shift in the Colorado River ecosystem within Grand Canyon. The Adaptive Management Program (AMP) for Glen Canyon Dam (GCD) was created in 1996 by the Department of Interior in response to social demands to extend multiple-use values to the Grand Canyon reach of the river. Since Glen Canyon Dam was constructed in the early 1960s, new social values have emerged that demand mitigation of degrading downstream impacts that compromise the integrity of Grand Canyon National Park. The mission of the AMP is to advise the Secretary of Interior on regarding how to mitigate downstream impacts that result from day to day operations of GCD and enhance the values for which Grand Canyon National Park was created. The Secretary may choose to do this through changes in dam operations or other management actions. The AMP is evidence of a shifting paradigm in water resource management. The reshuffling of political influence and control within the regulatory process has transferred substantial economic rents to non-traditional stakeholders (environmental non-profits, recreation and Native Nations) at the expense of traditional stakeholders (water and power). This creates a problematic dichotomy within the AMP. However, there are limits in the ability of science and technology to ameliorate resource conflict, especially in Grand Canyon where uncertainty exists regarding ecosystem response to management actions. Social choices may be needed to fulfill the intent of the enabling legislation surrounding the AMP. By using institutional barriers, traditional stakeholders threaten successful implementation of adaptive management. This atmosphere threatens management flexibility and is counterintuitive with current theories of adaptive environmental assessment and management (AEAM) aimed at rebuilding resilience within complex socio-ecological systems. Since AEAM is the method for exploring uncertainty and finding solutions to mitigate resource conflict any impediments to successful implementation should become subject to resolve.

Interactive Archaeology of the Colorado Plateau and Grand Canyon: Archaeological and Indigenous Perspectives

George Gumerman, IV, Northern Arizona University, Flagstaff, AZ

Abstract. The primary goal of the Interactive Archaeology of the Colorado Plateau and Grand Canyon project is to develop an educational, interactive, multimedia CD-ROM and web site that focus on the archaeology of the Grand Canyon and Colorado Plateau. The program provides public outreach on the effects of Glen Canyon Dam's operations, maintenance, and water flow on past and present cultures. Fourth through sixth grade learners will use the hands on, problem-based CD-ROM and accompanying web site to explore archaeology as a science, while conducting virtual archaeological research and learning Hopi, Zuni, and Hualapai views of their ancestral sites. Their mission is to create a virtual museum exhibit by exploring who lived in the Grand Canyon and how they existed. The student-centered, interactive, multimedia lessons allow students to interpret and quantify data from real sites and develop an understanding of the culture history of the Colorado Plateau and Grand Canyon. Digital video taped interviews with archaeologists and Native Americans provide multicultural voices that create an environment that is receptive to the needs of a diverse student population that learn in different ways. The project exposes students to different knowledge systems while also developing their respect for cultural diversity, values, and a sense of stewardship for archaeological resources. Learners become competent at understanding the prehistory of the Colorado Plateau and Grand Canyon. In the process, they develop important, lifelong science, mathematics, and technology skills necessary for students of the new millennium.

Trends in the Recruitment and Abundance of the Little Colorado River Humpback Chub Population

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Abstract. Humpback chub (Gila cypha) are a federally listed endangered fish endemic to the Colorado River. For over 15 years, a suite of federal, state, university, and private entities have conducted research on humpback chub in Grand Canyon. Though these efforts have fostered an increased understanding of the life history and ecology of this species, it has been difficult to integrate the data collected during these efforts to provide a comprehensive stock assessment of humpback chub in Grand Canyon. Since 2001, we have endeavored to reconstruct recruitment and abundance trends of this population utilizing a suite of open population models that rely on mark-recapture information collected since 1989. Additionally since 2000, closed population mark-recapture studies have been conducted to estimate humpback chub abundance within the Little Colorado River during spring and fall. These analyses and additional independent analyses of humpback chub relative abundance all indicate a declining trend in recruitment since the early 1990s. This recruitment trend is further reflected in a declining trend in adult abundance. It is hypothesized that factors such as increased densities of non-native fishes, introduced parasites, reduced near-shore rearing habitat, and changes in Colorado River hydrology may be acting singly or combination to affect the success of humpback chub recruitment. Non-native control measures in areas of the Colorado River deemed important to humpback chub have been initiated to better understand the relationship between non-native fish densities and humpback chub population dynamics.

Long-Term Monitoring to Determine Status, and Trends of Native Fish in the Colorado River through Grand Canyon, Arizona

Helene Johnstone, SWCA Environmental Consultants, Flagstaff, AZ

Abstract. In 2002, a stratified-random sampling monitoring program was initiated in Grand Canyon to track the status and trends of the fishes of the mainstem Colorado River. In the Colorado River in Grand Canyon, adult humpback chub (*Gila cypha*) are found in "aggregations" and are less commonly detected outside of those areas. Our sampling protocol was established to ensure that: 1) mainstem humpback chub are being effectively monitored, 2) potentially track humpback chub range expansion or contraction, 3) document humpback chub occurring outside of the known aggregation areas, and 4) document the distribution of other native and non-native fishes. The monitoring results do not provide absolute population estimates, but catch-per-unit-effort indices are intended to show trends over 5-year periods of time. Spatial and temporal distributional data for all native and non-native species will provide important baseline information from which to gauge changes as the result of management actions (e.g., mechanical removal of salmonids, temperature control device, and experimental flows).

Anticipated Effects of a Temperature Control Device on Fishes of the Colorado River Through Grand Canyon, Arizona

Richard A. Valdez[1], Melissa Trammell[2], Helene Johnstone[3], Stephen W. Carothers[3], and Ronald J. Ryel[4]

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Abstract. A Temperature Control Device (TCD) on Glen Canyon Dam may very well be the most important management tool for conserving the native fishes of Glen and Grand Canyons, particularly the endangered humpback chub. A TCD would also benefit the blue-ribbon tailwater trout fishery. However, a TCD may also be a perilous tool, fraught with substantial risks, and the possibility for ecological disaster, if improperly managed. A TCD has the potential to provide suitable spawning temperatures in the mainstem for humpback chub and other native fishes. Warmed mainstem temperatures may also allow existing nonnative fishes to expand and proliferate and invasion by new species, which may compete with and prey upon native forms. Releases of 14-15°C would provide optimum growth temperatures for rainbow trout in the tailwater fishery, but could also encourage expansion by the more predaceous brown trout further downstream. Water temperatures of greater than 15°C and 20°C would allow completion of the life cycle of the parasitic copepod (*Lernaea cyprinacea*) and the Asian tapeworm (*Bothriocephalus acheilognathi*), respectively, as well as the protozoan *Myxobolus cerebralis*, or whirling disease. An independent risk assessment shows that 11 nonnative fish species pose a potential significant risk, based on nine criteria. Greatest risk is from common carp, channel catfish, flathead catfish, and smallmouth bass. Risk to detrimental effects of the TCD can be minimized with appropriate management. The TCD will result in a significant biological landmark that must be properly managed and monitored with sufficient sensitivity. Decision criteria must be developed for guidance to implementation as well as suspension of TCD operations. A five-member "TCD Operations Team" should be established to advise the AMWG and to make immediate operational decisions. These criteria and guidance should be incorporated into the Glen Canyon Dam Annual Operating Plan.

Current Status and Trends of Lake Powell and Glen Canyon Dam Release Water Quality

William S. Vernieu, U.S. Geological Survey-BRD, Flagstaff, AZ

Abstract. As of October 1, 2003, Lake Powell's surface elevation was at 3603.72, its lowest level since May 19, 1973. Current storage is approximately 12.2 million acre-feet, 50 per cent of capacity (or live storage) and 46 per cent of total capacity. Reservoir elevation is projected to reach an elevation of 3585 by April 30, 2004.

As a result of these low reservoir levels, Glen Canyon Dam release temperatures have increased to the warmest levels since 1972, when filling of the reservoir resulted in consistently cool releases from the hypolimnion. The release temperature on October 1, 2003, was 11.7 deg C, an historic high and 2.1 deg C above the historic mean for that date during the period 1988 to 2003. Release temperature appears to be a function of warming at depth, associated with antecedent inflow volume, depth of penstock with changing reservoir levels, and degree of influence with convectively mixed surface water during winter cooling. As reservoir levels continue to decline under projected conditions, release temperatures are expected to be considerably higher in 2004.

Associated with the reservoir drawdown, large areas of deltaic sediment deposits in the tributary inflow areas have been exposed, resuspended, and deposited further into the reservoir. For example, at least 10 feet of sediment were aggraded at the mouth of Farley Canyon, 6 miles downstream of Hite Marina, during the spring runoff. Organic materials in this sediment have created a severe oxygen demand in the receiving strata of the reservoir. Dissolved oxygen levels throughout the reservoir are at historic low levels. Several areas have exhibited complete anoxia below the mixed surface layer. Some of these anoxic waters have shifted to chemically reducing conditions and are exhibiting measurable levels of hydrogen sulfide.

Salinity levels in Glen Canyon Dam releases, as represented by specific conductance measurements, have increased during the last several years with maximum levels occurring in mid-April. Maximum specific conductance is projected to be near 1000 uS (650 mg/L TDS) in April 2004.

An interesting feature of the reservoir drawdown is the rechannelization of the inflow tributaries in the exposed delta areas. A small waterfall has been documented in the Piute Farms area of the San Juan River, due to sedimentation of the old river channel and development of a new channel over a resistant geological stratum. The Colorado River upstream of Hite Marina is currently flowing over a shallow layer of sandstone and is expected to form a waterfall this winter as reservoir levels continue to decline.

The Utility of Bioenergetics Models in Grand Canyon Fisheries Research

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Abstract. Bioenergetics models of fish have been used to evaluate management alternatives in a variety of aquatic communities, including lakes, reservoirs, streams, and rivers. These models have been particularly useful for examining the effects of changes in temperature regimes, diets, and predator-prey interactions. Energy is balanced among growth, consumption, and losses (respiration, excretion/egestion, and activity), and the models can predict growth given a particular diet or the consumption needed to achieve a given growth increment. We are using a suite of models for important fishes in the Grand Canyon to assist managers in evaluating past, ongoing, or future changes in the system. Models are currently available for several species of interest, including rainbow trout, fathead minnow, striped bass, walleye, speckled dace, and others, and we are developing a model for the endangered humpback chub. This suite of models should be particularly useful in evaluating the effects of historical temperature change on fish growth, the potential impacts of a temperature control device (TCD) at Glen Canyon Dam, mechanical removal of non-native fishes from Grand Canyon near the Little Colorado River, or diet shifts that might occur following a natural (climate shift, e.g.) or management change in the system. We will present preliminary results of analyses at the Symposium. Bioenergetics models should be an effective way to integrate some of the physical and biological processes in the complex aquatic ecosystem of the Grand Canyon.

Recovery Goals For Humpback Chub and Adequacy of Management Actions in Grand Canyon, Arizona

Richard A. Valdez[1]**,** Robert T. Muth[2], Thomas Czapla[3], Ronald J. Ryel[4,] Stephen W. Carothers[4]

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Abstract. Recovery goals for Colorado pikeminnow, razorback sucker, humpback chub, and bonytail were posted under a Notice of Availability in the Federal Register on September 10, 2001, and signed by the Regional Director of the U.S. Fish and Wildlife Service on August 1, 2002. Each species recovery goals contain site-specific management actions; objective, measurable criteria; and estimates of time and cost to achieve recovery, consistent with Section 4 of the Endangered Species Act of 1973, as amended. Humpback chub recovery goals require that for delisting each of the six populations must be maintained over an 8-year monitoring period, such that the trend in adult point estimates does not decline significantly, mean estimated recruitment equals or exceeds mean annual adult mortality, and three core populations are maintained such that each population point estimate exceeds 2,100 adults. Eleven recovery factor criteria in the upper basin and 12 in the lower basin are required to be achieved for delisting. For the Grand Canyon population, recovery factor criteria include: appropriate habitats provided, adequate flow regimes provided, temperature control device implemented if feasible and necessary, adequate protection from overutilization, levels of Asian tapeworm control identified, procedures for stocking nonnative fish finalized and implemented, levels of nonnative fish control identified, adequate habitats protected, conservation plans developed and implemented, State and Federal emergency response plans implemented, and measures finalized and implemented to minimize the risk of hazardous materials spills into the Little Colorado River. Compliance and adequacy of management actions in Grand Canyon will be examined relative to requirements of species recovery goals.

Genetic Interrelationships of *Gila cypha* in the Colorado River Ecosystem

Marlis R. Douglas, Michael E. Douglas, Colorado State University, Fort Collins, CO

Abstract. Life history of *G. cypha* in the Colorado River Basin is mostly enigmatic, and interrelationships among subpopulations are virtually unknown. Lack of an historic baseline further complicates understanding of present-day patterns, and causal relationships between physical and biological parameters are merely the source of speculation. The most pressing questions pertain to genetic distinctiveness of local populations in the Colorado River Basin, the interrelationships among these populations, and how the sum can be adaptively managed in a perturbed environment. The objectives of this ongoing study are therefore to (a) infer interrelationships among populations of *G. cypha* within the basin, (b) to identify, if possible, genetically distinct units, and (c) to derive a management strategy for this endangered species. In this presentation, we deal with issue (a) through an assessment of genetic interrelationships among 9 populations based on amplification and sequencing of 1,820 base pairs from four rapidly evolving mitochondrial (mt) DNA markers (ATPase 8 & 6, ND2, and D-loop). Analyses revealed low levels of genetic variation, both within and among populations. While this is surprising, given the number of specimens and amount of sequence data generated, it is congruent with findings in other big river fish from the Colorado River basin. Our basin-wide assessment of genetic diversity in Flannelmouth Sucker (*Catostomous latipinnis*) also revealed similar patterns of low genetic diversity. Potential causes for such low genetic diversity and implications for management and recovery are discussed.

Effective Population Sizes for *Gila cypha* in the Colorado River Ecosystem

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Abstract. Effective population size (N_e) is an important parameter in population and quantitative genetics. It derives from the premise that not all individuals in a population contribute gametes with equal probability to the next generation. In simple terms, N_e represents the size of an idealized, randomly mating population that would produce the same levels of inbreeding and (potential) genetic drift as observed in the study population. Recent advances in DNA technology and microcomputer engineering now provide a new and innovative platform for estimating N_e, and we have applied these to gain insight into the status of *G. cypha* within the Grand Canyon ecosystem. Unpublished mtDNA sequences (i.e., 640 bp of ND2, 650 bp of ATPase 6 and 8, and 350 bp from the D-loop region) were derived from 30 adult *G. cypha* captured in the Little Colorado River (LCR). The three mtDNA regions were coalesced and analyzed as a single sequence of 1,640 bp. Results yielded an N_e of 374. Size of the LCR spawning population was calculated as 8,073 individuals (an average of open population estimates for *G. cypha* in the LCR during March-May of 1992-93). An N_e/N ratio of 0.046 was calculated. The LCR population is relatively devoid of mtDNA sequence variation, probably as a result of an historic bottleneck during its evolutionary history. It has not as yet recovered. This exercise is an example of how molecular data can provide insights into the evolution of an endangered species. The manner in which these data can be used to manage the species within an altered ecosystem is discussed.

Site Fidelity of Humpback Chub in Grand Canyon

Craig P. Paukert and Lewis G. Coggins, U.S. Geological Survey-BRD, Flagstaff, AZ

Abstract. We analyzed site fidelity of the federally endangered humpback chub across two spatial scales (i.e., entire Grand Canyon and within the Little Colorado River [LCR])) and four temporal scales (1-4 years) to better direct conservation and management efforts for recovery of this species. Humpback chub showed strong site fidelity, regardless of the spatial and temporal scale evaluated. Of the 14,089 recaptures throughout all seasons and locations in Grand Canyon, 85% were captured and recaptured in the LCR. However, some fish did move >154 km throughout Grand Canyon between capture and recapture, suggesting limited mixing occurs throughout Grand Canyon. Only 5.5% of the 1,103 recaptures recorded in the LCR during spring (March-May) were collected in the Colorado River the following spring. Forty-two percent of the 1,045 recaptures in the LCR from the previous spring were within 1 km of their capture location, suggesting site fidelity within the LCR. This trend was also evident for fish at liberty up to 4 years. Humpback chub mix throughout the river and its tributaries and genetic conservation may need to be at the canyon-wide scale. However, monitoring and sampling can be at a smaller scale focusing in the LCR.

Status, Trends and Long-term Monitoring of the Lees Ferry Tailwater Fishery, 1991-2003

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Abstract. We examine the status and trends of rainbow trout (*Oncorhyncus mykiss*) in the Lees Ferry tailwater (Colorado River below Glen Canyon Dam, Arizona) based on electrofishing and creel data from 1991-2003. Inception of higher minimum and more stable flows since 1991 was supportive of high relative densities of small trout (<305 mm TL) while CPE of larger trout (>305 mm TL) declined. Angler CPE increased 3-fold from 1993 through 1998 but has since declined. Proportional stock density declined from 55 in 1991 to 4 in 2003, which coincides with increasing relative abundance of juvenile fish, declines in fish growth rates, and evidence of food limitation among adult fish. Preliminary data collected in 2003 indicate an increase in relative condition of young fish (< 405 mm TL). We attribute this increase in relative condition most likely to declines in fish density and lack of spawning activity in 2002. Since 1991, enhanced flow regimes and improved survival of age 0 rainbow trout has led to over-recruitment and consequent density dependent constraints on growth and condition. Managers have recently increased daily fluctuating flows below Glen Canyon Dam to limit recruitment of young fish to the adult population and thereby alleviate density dependent effects on rainbow trout growth in the Lees Ferry Fishery.

One-Fish, Two-Fish, Red-Fish, Blue-Fish:

An Evaluation of the Utility of Snorkel Surveys for Estimating Population Size and Tracking Trends in Relative Abundance of Rainbow Trout in the Lees Ferry Reach of the Colorado River

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Abstract. Reliable indices of abundance and absolute estimates of population size are critical for management of fish resources in the Colorado River in Grand Canyon. Boat electrofishing has been used to enumerate rainbow trout in the Colorado River in Grand Canyon for almost two decades but suffers two major weaknesses. First, absolute population estimates derived solely from shoreline density estimates must guess at the density of fish in offshore areas. Second, even if shoreline densities are only being used to index population levels, it is necessary to assume that the ratio of fish in shoreline to offshore areas is constant among sample periods. To address these issues, snorkel surveys were implemented in the Lees Ferry reach in Jun. '01, Jun. and Oct. '02, and Apr. '03. Diel studies were used to examine the offshore-onshore movement of fish over a 24-hr.+ period in responses to changes in light intensity and discharge. Densities of fish in shoreline and offshore areas were used to evaluate the reliability of snorkeling to estimate trends in relative abundance and population size. Shoreline density estimates derived from boat electrofishing and snorkeling were compared.

There were very large differences in the number of fish observed over a 24-hr. cycle during the diel studies, however the extent of these differences varied across seasons. The ratio of the average daytime count to the peak night count was 0.47 at 8-mile in Jun. '02 and ranged from 0.36 to 0.39 across the 3 sites in Oct. '02 (Table 4). In contrast, the ratio of the average daytime to peak nighttime counts in Apr. '03, the peak of the spawning season, was much higher, ranging from 0.62 at the 8-mile site to 0.97 at the 3.5-mile site. The offshore-onshore distribution of fish appeared to depend on light availability, discharge, and spawning behavior. During daylight hours trout were distributed relatively evenly along the cross-section while at night fish moved onshore. As discharge continued to drop during the late evening and early morning, we observed a slight offshore migration as depth likely become limiting in the innermost lanes. These shifts were much more subtle at some sites in Apr. when spawning behavior reduced offshore-onshore movement. Diel activity patterns of stream-dwelling fish can be viewed in the context of individuals making decisions about the trade-of between foraging and the risk of predation (Bradford and Higgins 2001). A useful construct is the "minimize u/g" rule (Metcalfe et al. 1999), which suggests that fish should occupy habitats that minimize the ratio of mortality risk (u) to growth (g). This construct provides a feasible explanation for the onshore-offshore movement patterns we observed at the diel sites.

Shoreline fish densities estimated by snorkel surveys declined noticeable from Jun. ’01 (6.2 fish/100 m2) through Apr. ’03 (1.9 fish/100 m2). The density of fish in offshore zones was typically about 50% of the density in shoreline areas but varied considerably among trips. The ratio in Oct. ’02 averaged across habitat types was only 0.17 compared to 0.95 in Apr. ’03. Total population estimates declined from 100,000 to 50,000 fish between Jun. and Oct. ’02 and then increased to about 80,000 fish by Apr. ’03. This unlikely change in population estimates may be driven by biases in offshore densities due to differences in underwater visibility across sample periods.

The relationship between estimates of shoreline fish density based on snorkel surveys during the day and those based on boat electrofishing at night was weak. Shoreline densities estimated by electrofishing explained between 20 and 30% of the variance in snorkel-based estimates. The ratio of shoreline densities from snorkeling to electrofishing progressively declined from 2.1 in Jun. ’01 to 0.5 in Apr. ’03. Shoreline densities derived by snorkeling showed a 3-fold decline over the sample periods while those derived by electrofishing were relatively similar (14.3-17.0 fish/100 m). The systematic change in the ratio of shoreline densities based on snorkeling vs. electrofishing surveys from Jun. ’01 to Apr. ’03 is potentially indicative of hyperstability in the electrofishing index of abundance.

Long-term Monitoring of Rainbow Trout, Brown Trout, and Common Carp in the Grand Canyon

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Abstract. Robust long-term monitoring of aquatic populations is important to adaptive management programs because it characterizes a "baseline" or antecedent context in which response of biota to changing management policies—or experiments—can be interpreted. We began development of a long term monitoring program for rainbow trout, brown trout and common carp in 2000. Resampling of data collected in 2000-2001 suggests that approximately 800, 300 second electrofishing samples distributed throughout the Grand Canyon are necessary to detect 10% linear change over a five-year period. Efforts are now also being concentrated near the Little Colorado River and Bright Angel creek where experimental removal of non-native fish is occurring. Data from 2003 suggests that there has been a significant decrease in the density of rainbow trout in the ten-mile reach bracketing the Little Colorado River.

Diet and Incidence of Predation for Rainbow and Brown Trout near the Little Colorado River, Grand Canyon During Winter 2003

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Abstract. Considerable evidence suggests that piscivory by non-native species; rainbow (RBT) and brown trout (BNT) may be partially responsible for the recent decline in the recruitment of humpback chub near the Little Colorado River (LCR), Grand Canyon. An extensive research effort has been recently applied to reduce non-native fish abundance proximal to the LCR; unfortunately, dietary information on different fish species for this particular system is not well known. Seasonal differences in suspended sediment loads occur upstream versus downstream of the LCR, and the resultant turbidity levels appear to influence the abundance, distribution and feeding behavior of these visual sight-feeders. Young small-bodied native and non-native fish disperse into the Colorado River mainstem associated with LCR freshets. It is hypothesized that predation from cold water salmonids represents a significant mortality source to these LCR emigrants downstream of the LCR confluence. Therefore, vulnerable small sized fish represent a proportion of the overall foodbase in this ecosystem. Additionally, the availability of some aquatic invertebrates is strongly coupled to primary production, which is inversely correlated to increased turbidity from tributaries. For this reason, a dietary study has been implemented in parallel with the depletion effort to gain insight on trophic responses to spatial and seasonal changes occurring between and among the different size-age classes of RBT and BNT; as well as their interactions associated with changes to population densities (intra- and interspecific) under varying levels of turbidity and aquatic food resources. Preliminary findings for winter diet assessment indicate dietary differences and incidence of predation between RBT and BNT for high, moderate and low fish densities. There was a high incidence of observed predation by BNT on native fish inclusive of humpback chub. Whereas, RBT had the highest fish densities yet exhibited lower incidence of predation. The largest proportion of the trout diet consisted primarily of simulid larvae. Other aquatic invertebrates were observed such as *Gammarus lacustris* "scuds" and chironomid "midges", yet these represented a very small proportion of the diet. High turbidity levels were associated with a greater proportion of RBT exhibiting empty gastrointestinal tracts suggesting that lower water clarity impacts feeding success and/or invertebrate density.

1996-2000 Avifaunal Monitoring Along the Colorado River

John Spence, National Park Service, Page, AZ

Abstract. Between 1996 and 2000 surveys were conducted on the breeding riparian birds, wintering terrestrial birds, and wintering aquatic birds between Glen Canyon Dam and Lake Mead along the Colorado River. This study was conducted to further refine inventory and monitoring protocols, and to collect baseline data on the avifauna and potential effects of dam operations. Winter aquatic birds were strongly controlled by turbidity gradients in the river, with most birds seen near or above Lees Ferry. Winter terrestrial bird communities were extremely diverse, with 75 species detected on 380 area searches. Many new species were reported for the study area. During the study 31 breeding or potentially breeding species were detected in riparian vegetation by 1700 point counts and 540 area searches. The most common species were Lucy's warbler and Bell's Vireo. The winter and breeding terrestrial bird communities were similar in their response to habitat characteristics. Power was adequate to detect changes in riparian habitat and some winter and breeding bird species, but was lacking for most rarer species. Distance estimation techniques revealed that only three species were sufficiently abundant below Lees Ferry for the method to be useful. Recommendations for long-term monitoring are made.

Stranding of Rainbow Trout During Experimental Fluctuating Releases from Glen Canyon Dam on the Colorado River

Wendy Batham, EcoPlan Associates, Inc., Mesa, AZ

Abstract. The purpose of this study was to determine the extent of stranding among non-native rainbow trout (RBT) within the Lees Ferry reach of the Colorado River resulting from fluctuating flow releases during a three-month period (January 2003 through March 2003) from Glen Canyon Dam. The fluctuating flows were part of an experiment intended to disrupt spawning and subsequent survival of rainbow trout. One expected, but unintended consequence of fluctuating releases during the experiment, was stranding of adult trout in shallow, lower flow areas.

EcoPlan Associates, Inc. estimated a total of 1,742 RBT adults became stranded during this three-month study. We estimated seven percent of stranded fish (125 fish) were dead or dying while 93 percent (1,617 fish) would have lived. The mean total length of rainbow trout found was 378 millimeters (SD = 63, n = 36), as compared to an average of 234 millimeters caught by Arizona Game and Fish during adult population surveys.

Stranding numbers observed during the 2003 experiment (503 fish) differed from those observed in 1990 by Angradi, *et al*. (1924 fish). We found stranded trout in approximately the same sites as Angradi but direct comparison of total numbers of stranded trout with the earlier stranding study was impossible due to differences in: (1) length of the study period (3 months vs. 18 months); (2) number of surveys; (3) flow conditions and ramping rates; and (4) water temperatures in stranding pools. Also, such a comparison was probably inappropriate since the Angradi study was set to determine if stranding took place over an 18-month period under a variety of seasonal conditions while this survey was intended to document the extent of stranding during a short, 90-day fluctuating flow experiment.

The Hopi Tribe Monitoring Project

Kristin Huisinga, Michael Yeatts

The Hopi Tribe - Hopi Cultural Preservation Office, Flagstaff, AZ

Abstract. The Hopi Tribe is in the final stages of developing an integrated long-term monitoring plan for terrestrial, cultural, and physical resources in Grand Canyon. This talk presents the preliminary results of a two-year effort to integrate tribal perspectives into Grand Canyon Monitoring and Research Center's long-term monitoring program.

Distribution and Trophic Interaction of the Invasive New Zealand Mudsnail in the Colorado River, Below Glen Canyon

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Abstract. The alien New Zealand mudsnail, *Potamopyrgus antipodarum*, became established in 1995 within the study site. Its potential for rapid population growth and high habitat tolerance increases its ability to spread to unaffected areas and compete with macroinvertebrates by limiting periphyton growth. As of October 2002 it was not in tributaries where native fish spawn, but was found in the mouths of five tributaries. Our 12-year benthic monitoring program showed cobble bar snail density from 1991-1995 comprised <1% of total macroinvertebrate numbers (340/m^2; ± 87sd; n=151) for the entire study site. From 1996 - 2002 snail density increased from 5% to 99%. However, non-snail macroinvertebrates also increased 6.3 times over pre-1996 data (2046/m^2; ± 880 sd; n=182). These other macroinvertebrates were comprised of nematodes, flatworms, and various Oligocheates. In October 2002 we estimated the biomass of epiphytic diatoms, *P. Antipodarum* and other grazers from six cobble bars to determine the amount of energy that this snail was consuming. We estimated that >75% of the available diatom biomass could be consumed by *P. Antipodarum*, in comparison to pre-invasion epiphytic diatoms estimates. Implications of these "trophic dead-end" aliens, lack an aerial stage for insectivorous consumers and digestion by fish, to aquatic ecosystem structure will be discussed.

Poster

Abstracts

Analysis of PIT Tag Data from Bluehead Suckers (*Catostomus discobolus*) in the Little Colorado River in Grand Canyon, 1991-2003

David Ward, Arizona Game and Fish Department, Flagstaff, AZ

Abstract. Over 6,600 bluehead suckers (*Catostomus discobolus*) were tagged with Passive Integrated Transponders (PIT) in the Colorado and Little Colorado Rivers (LCR) from 1991 to 2003. Only 603 of these fish have been recaptured with only 309 fish at large for more than 60 days. Recaptures came almost exclusively from the LCR (574 of 603). Maximum time at large was 5.3 years. This fish was initially tagged at 250 mm total length (TL) indicating a life span of at least 8 years. Bluehead suckers move throughout the lower 12 km of LCR and as far as 65 km upstream and 30 km downstream from their original capture locations in the mainstem Colorado River. Small hoopnets set from March to May were used to analyze catch per unit effort (CPUE) trends for bluehead suckers in the LCR. Length frequency histograms indicate age-0 bluehead suckers often reach 80 – 90 mm TL by May of the first year. No significant changes in CPUE or size structure of adult bluehead suckers (>190 mm TL) are evident from 1991 to present, but CPUE of age-0 bluehead suckers appears to be inversely correlated with LCR spring discharge.

Assessment of the Flannelmouth Sucker Population in the Little Colorado River

R. Scott Rogers, Arizona Game and Fish Department, Flagstaff, AZ

Abstract. We used the PIT tag mark-recapture database from 1991 - 2002 to model recruitment and population trends for flannelmouth suckers in the Little Colorado River.
We utilized the mark recapture program Supertag.exe developed by Carl Walters and Lew Coggins.

Flannelmouth sucker recruitment between 1991 and 1999 was highest in 1993 and 1995. The local population at the Little Colorado River appears stable with between 2000 and 4700 fish over 150 mm. The population estimates developed with suppertag.exe are similar to the estimates produced by Douglas and Marsh for the years 1992-1995.

Comparison of Electrofishing and Trammel Netting Variability for Sampling Native Fishes in Grand Canyon, Colorado River, Arizona

Craig Paukert, U.S. Geological Survey-BRD, Flagstaff, Arizona

Abstract. The variability in size structure and relative abundance (CPUE; number of fish ≥200 mm collected per hr of electrofishing or trammel netting) of three native Colorado River fish, the endangered humpback chub *Gila cypha*, flannelmouth sucker *Catostomus latipinnus* and bluehead sucker *C. discobolus* collected from electrofishing and trammel nets during 1992-1993 at RKM 96.6 to RKM 104.7 was assessed to determine which gear was most appropriate to detect trends in relative abundance of adult fish. Coefficient of variation (CV) of CPUE ranged from 268 to 656 for electrofishing and 136 to 648 for trammel netting, depending on season, diel period, and species. Mean CV was lowest for trammel nets for both humpback chub (P=0.004) and flannelmouth sucker (P=0.10), regardless of season or diel period. Only one bluehead sucker 200 mm or longer was collected with electrofishing. Electrofishing and trammel netting CPUE was not related for humpback chub (r=-0.32, P=0.43) or flannelmouth sucker (r=-0.27, P=0.46) in samples from the same date, location, and hour set. Electrofishing collected a higher proportion of smaller (<200 mm) humpback chub (P<0.001), flannelmouth suckers (P<0.001), and bluehead suckers (P<0.001) than trammel netting, suggesting conclusions from one gear may not be the same as the other gear. This is likely because these gears fish different habitats, which are occupied by different fish life stages. To detect a 25% change in CPUE at a power of 0.6, at least 700 trammel net sets or 1722 electrofishing samples were needed in this 8 km reach. This unattainable amount of samples for both trammel netting and electrofishing indicates that detecting annual changes in CPUE may not be practical and analysis of long-term data may be needed to assess trends in CPUE of Grand Canyon native fishes, and likely other rare fishes as well. A proper sampling design using trammel nets may be more appropriate than electrofishing to evaluate long-term trends in relative abundance of adult native fish in Grand Canyon.

Designing an Effective Avian Monitoring Program to Meet the Needs of the Grand Canyon Monitoring and Research Center's Adaptive Management Program

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Abstract. GCMRC has specific goals to study the effects of the operation of Glen Canyon Dam on downstream resources within the Colorado River ecosystem (CRE) and to identify an optimal design for an efficient and effective long-term monitoring program. In turn, this scientific information drives the Adaptive Management Program, which allows for flexibility in research objectives in response to increased understanding of the resources. Other state and federal organizations concerned with maintaining species, ecosystems, and processes on the landscape are also currently developing regionally based monitoring programs that include avian monitoring. Thus it is an appropriate time to assess the methodologies and results of previous GCMRC avian monitoring projects and their ability in meeting GCMRC's goals and adaptive management needs, including the need to determine linkages among floral and avifaunal elements. This project seeks to identify an appropriate design for monitoring avifauna in the CRE based on an evaluation of past GCMRC monitoring and other regional programs currently being developed for long-term monitoring of bird populations.

Development and Implementation of Lake Powell Water Quality Database

William S. Vernieu, U.S. Geological Survey-BRD, Flagstaff, AZ

Abstract. Thirty-eight years of water quality observations have been compiled and stored in WQDB, the Lake Powell water quality database, developed by the GCMRC Integrated Water Quality Program. WQDB is a relational database, currently residing in Microsoft Access, containing linked tables representing different types of information pertaining to Lake Powell water quality. The database currently holds complete records for site visits and general field observations, water quality profile information, and results of major ion and nutrient analyses throughout the history of Lake Powell's existence. The database contains information on 3216 site visits, 11193 major ion samples, 3029 nutrient samples, and 57993 individual water quality measurements. Biological tables representing chlorophyll, phytoplankton, and zooplankton sample analyses will be completed in early FY 2004.

By means of queries to the linked tables, a vast amount of information is available to researchers and resource managers. Output is easily formatted for other statistical and graphical analysis software, as well as providing input files for simulation models. As this database undergoes further updates and design refinements, it will be migrated to the GCMRC Oracle database to integrate with other GCMRC information and facilitate web-based information access.

Dissolved Organic Carbon Mass Transfer Under Contrasting Flow Conditions

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Abstract. Water level fluctuations in response to hydropower demands can have an impact on the transport of organic matter and nutrients in river systems. The diurnal cycle of wetting and drying of the river channel margins produces a biologically, chemically, and physically dynamic habitat capable of large shifts in carbon and nutrient retention and release. For 8 days in late May 2003 samples were collected at the Lee's Ferry gauging station to assess the impact of flow fluctuations (fluctuating flows, steady flows, return to fluctuating flows) on dissolved organic carbon mass transfer out of the Glen Canyon reach of the Colorado River. Samples were collected at 1-3 hour intervals from nearshore surface waters at Colorado River mile 0. The dissolved organic carbon concentrations (mg C L^{-1}) and discharge values (m^3 sec^{-1}) were combined to estimate mass transport out of the reach. These 8 days included days of normal flow/water level fluctuation, 3 days of steady flows, and a return to fluctuating flows for 3 additional days. It is predicted that organic matter transport out of the reach will be lowest during the 3 days of steady flows and highest during the 2-day period following the return to diurnal flow fluctuation.

Dynamics of Avian and Arthropod Communities Across Distinct Vegetation Zones Along the Colorado River in Grand Canyon

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Abstract. We examined avian and arthropod abundance and density in two distinct vegetation zones along the Colorado River in Grand Canyon National Park. Riparian breeding bird densities have increased along the Colorado River in Grand Canyon National Park in the last 30 years due to the establishment of a new riparian zone after the completion of Glen Canyon Dam. This post-dam riparian vegetation zone is composed predominantly of exotic tamarisk (*Tamarix chinensis*). The pre-dam vegetation zone is predominantly native mesquite (*Prosopis glandulosa*) and catclaw acacia (*Acacia greggii*). A higher overall abundance and density of birds was detected in the pre-dam, native vegetation throughout the breeding season. Bird densities remained consistent in pre-dam vegetation whereas densities of birds almost doubled in the tamarisk during mid-summer, then dropped. Bird community composition was different between pre- and post-dam vegetation. The highest abundance and density of arthropods was found in the exotic, post-dam vegetation. Inclusion of the introduced leafhopper (*Opsius stactogalus,* an insect species specific to tamarisk) into the analysis makes the overall abundance of arthropods higher in the post-dam zone. If *O. stactogalus* is removed from the analysis, there are significantly more arthropods considered to be "high-quality bird food", in pre-dam vegetation. Seasonal differences found in avian abundance and densities between zones may be linked to ecological plasticity of birds responding to arthropod availability and an increase in fledged birds.

Effect of a 31,000-cfs Spike Flow and Low Steady Flow on Benthic Biomass and Drift Composition in the Lees Ferry Reach, Colorado River

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Abstract. Experimental flows consisting of 31,000 cubic feet per secondspike flows and low seasonal steady flows were conducted during March-September 2000. The benthic community and drift in the Lees Ferry tailwater were among the resources potentially impacted by these flows. We collected benthic invertebrates, periphyton, macrophytes and drift prior to and after the 31,000-cfs spike flows and during the low summer steady flows of 2000. Samples were collected from standard monitoring sites used in 1996 and 1997. We compared drift and benthic mass and composition between summer sample periods and from previous years efforts.

Drift biomass was reduced during the low steady flows following the spike flow in March. Periphyton biomass, chlorophyll *a* and invertebrate densities were consistent with those observed in 1996 and 1997. Macrophyte distribution and biomass was not reduced by the spike flows, and macrophyte biomass was higher than that observed in previous years. Benthic Gammarus and Chironomidae densities were not reduced by the spike flow and followed seasonal trends in abundance consistent with previous years. Gastropod densities were an order of magnitude higher than previously observed because of a change in species composition to one dominated by the non-native New Zealand mud snail.

Effects of Discharges from Glen Canyon Dam on Potential Rearing Habitat of Humpback *Chub (Gila cypha)* at the Confluence of the Little Colorado and Colorado Rivers in Grand Canyon, Arizona

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Abstract. The Colorado River (CR) and its tributaries, prior to river regulation, was home to a unique assemblage of warm water fish species including cyprinids and catostomids. These fish evolved in an environment characterized by wide fluctuations in temperature and turbidity. Regulation by Glen Canyon Dam has resulted in a significant reduction (97% loss) in warm water habitat within Grand Canyon, a concomitant loss in both species and population numbers of the fish assemblage, and an increased reliance on unregulated tributary confluence areas for available habitat and subsequent recruitment success by native fishes.

Currently, the Little Colorado River (LCR) is the only documented location of successful humpback chub reproduction in Grand Canyon. At this confluence, the LCR's velocity, depth, and total ponded area is a direct function of the mainstem CR's interaction with the complex local morphology. The installation of Glen Canyon Dam changed this interaction frequency, causing drastic changes to this available aquatic habitat on a daily basis instead of the pre-dam seasonal basis.

This study asked questions about the areal extent of ponded, low-velocity habitat, identified as suitable for humpback chub, at the CR-LCR confluence. Specifically, we investigated how habitat changes (temperature, velocity and extent of ponding) at the confluence are related to discharges from Glen Canyon Dam when the LCR is at base flow.

Factors Affecting Condition of Flannelmouth Sucker in the Colorado River, Grand Canyon, Arizona

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Abstract. The impoundment of the Colorado River by Glen Canyon Dam in 1963 created a highly regulated environment in Grand Canyon that altered the native fish populations, including flannelmouth sucker *Catostomus latipinnis*. Flannelmouth sucker were sampled from 1991-2001 to determine seasonal and annual trends in fish condition (i.e., relative weight; Wr). Mean Wr peaked during the pre-spawn and spawning periods and was lowest in summer and fall, but was never below 93. Dam discharge during summer (June to August) from Glen Canyon Dam was positively related to flannelmouth sucker condition, possibly because of increased macroinvertebrate abundance during higher water flows. Condition of flannelmouth sucker and the endangered humpback chub *Gila cypha* were positively related, suggesting mechanisms to enhance one native fish may benefit other native fish as well. Mean Wr values lower than 90 during the post spawn and summer and lower than 100 during the pre spawn and spawn may warrant further investigation and suggest declining condition compared to historical (1991-2001) flannelmouth sucker condition. Increased dam discharge that increases summer-wetted area may provide benefits for this native fish.

Genetic Assessment of Age-0 Trout Produced in the Grand Canyon Tributaries of the Colorado River

Kyle C. Hanson[1], Todd W. Kassler[2], Julie E. Claussen[2], John M. Epifanio[2]
David P. Philipp[2]

Abstract: In February and April, 2002 age-0 trout were collected (by electrofishing, seining, and dip netting) from nine of the tributaries of the Colorado River between Glen Canyon Dam and Lake Mead. Samples were frozen on liquid nitrogen, sent to the Illinois Natural History Survey in Champaign, Illinois, and analyzed genetically using standard protein electrophoresis techniques to determine if they were rainbow (*Oncorhynchus mykiss*) or brown trout (*Salmo trutta*). In addition, adults of both species were collected from the main channel at various points throughout the Grand Canyon, and liver, white muscle, and eye tissues were dissected, frozen and analyzed in the same way to assess genetic variation. Four tributaries were found to produce age-0 *S. trutta* individuals (Bright Angel Creek, Pipe Creek, Shinumo Creek, and Tapeats Creek). In previous collections made from these same tributaries in 1986 and 1991 age-0 brown trout were sampled only from Bright Angel Creek, indicating a recent expansion of the range of reproduction of this species within the Grand Canyon. In addition, the very low level of genetic variability observed among the adult brown trout collected from the main channel suggests that these fish may have arisen from a relatively few source fish that potentially colonized and successfully spawned in the main channel of the Colorado River, and may not be simple outmigrants from Bright Angel Creek.

Grand Canyon Riverbed Sediment Changes, Experimental Release of September 2000 - A Sample Data Set

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Abstract. An experimental water release from the Glen Canyon Dam into the Colorado River above Grand Canyon was conducted in September 2000 by the U.S. Bureau of Reclamation. The U.S. Geological Survey (USGS) conducted sidescan sonar surveys between Glen Canyon Dam (mile -15) and Diamond Creek (mile 220), Arizona to determine the sediment characteristics of the Colorado River bed before and after the release. The first survey (28 Aug to 5 Sep 2000) was conducted before the release when the river was at its Low Summer Steady Flow (LSSF) of 8,000 cfs. The second survey (10 to 18 Sep 2000) was conducted immediately after the September 2000 experimental release when the average daily flow was as high as 30,800 cfs as measured below Glen Canyon Dam. Sidescan sonar data from the USGS surveys were processed for segments of the Colorado River from Glen Canyon Dam (mile -15) to Phantom Ranch (mile 87.7). The surveys targeted pools between rapids that are part of the Grand Canyon Monitoring and Research Center physical sciences study.

Maps interpreted from the sidescan sonar images show the distribution of sediment types (bedrock, boulders, pebbles or cobbles, and sand) and the extent of sandwaves for each of the pre- and post-flow surveys. The changes between the two surveys were calculated with spatial arithmetic and had properties of fining, coarsening, erosion, deposition, and the appearance or disappearance of sandwaves. This poster describes GIS spatial data files for this project and provides examples of the data from the Colorado River near mile 2 below the confluence of the Paria and Colorado Rivers.

Influence of Topographic Complexity on Aquatic Ecosystems: Solar Insolation Estimates for the Colorado River

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Abstract. Rugged topography along the Colorado River in Glen and Grand canyons, exemplifies features common to canyon-bound streams and rivers of the arid southwest. Physical relief influences regulated river systems, especially those that are trophically altered and dependent on aquatic primary production. We measured and modeled instantaneous solar flux in a topographically complex environment to determine where differences in daily, seasonal and annual solar insolation occurred in this river system. We used an Arc-Info routine referred to as hillshade function to generate binary grids that represented areas of shadow and illumination for a given set of azimuths and altitude angles. Modeled estimates for clear conditions corresponded closely with observed measurements for both instantaneous photosynthetic photon flux density (PPFD: Φmol m^{-2} s^{-1}) and daily insolation levels (relative error 2.3%, CI ± 0.45, std 0.3, n = 29,813). At a system-wide scale, topographic complexity generates a spatial and temporal mosaic of varying solar insolation. This solar variation is a predictable consequence of canyon and channel orientation, geomorphology, elevation angles and viewshed. We developed and will make available a computational program that numerically solves for solar time, spatial coordinates and solar insolation so that other researchers may resolve similar questions in this and other topographically complex systems. The solar insolation model was written in Visual Basic for Applications, with several subroutines designed for Microsoft Excel worksheet environment. Documentation, downloading, and access to the model and updates are available at: http://www.gcmrc.gov.

Integrated Monitoring of Terrestrial Riparian Resources Along the Colorado River in Grand Canyon

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Abstract. Monitoring of diverse resource types in large and complex systems is often done in piecemeal fashion, with tasks divided among unconnected groups along taxonomic or methodological lines. Here we present the framework for monitoring the effects of discharges from Glen Canyon Dam in Grand Canyon National Park which recognizes the connectedness of many terrestrial elements in the Colorado River corridor. Joint sampling trips simultaneously collect data on habitat productivity (vegetation structure) and the abundance and composition of breeding birds, waterfowl, small mammals, herpetofauna and terrestrial invertebrates at a series of sites over the entire year. Sites are revisited at one to three year intervals in an augmented serially rotating panel design in order to balance change detection power against observer impacts and canyon-wide representation. Sites are divided into three zones based on hydrology: a pre-dam xeroriparian zone, a shoreline zone below the current range of non-emergency flows, and a post-dam riparian zone between the two. Data collected in the first two years shows several interesting patterns. First, vegetation density is more stable than we would expect based on large differences in precipitation in 2001 and 2002. Second, breeding bird densities within sites differ between years, but shift among zones depending on the where invertebrates and other food sources are greatest. Third, vegetation density sets an upper bound on breeding bird density rather than predicting it outright. Fourth, mammal diversity and density is highest in the pre-dam zone where productivity is lower. Fifth, herpetofaunal densities and diversity are highest in the interfaces between hydrologic zones, especially between the lower two. These patterns have important implications for efficiencies and insight gained by monitoring many resources in an integrated fashion.

Lake Powell Assessment Findings: 1964-Present

Susan Hueftle, William Vernieu, U.S. Geological Survey-BRD, Flagstaff, AZ

Abstract. The effects of the construction and operation of Glen Canyon Dam have been extensively studied, documented, and manipulated in the downstream environment in Grand Canyon. While data has been collected from Lake Powell throughout its filling history, there had been no concerted effort to evaluate the impacts of dam operations on the physical, biological, and chemical processes of the reservoir and downstream releases. Using data from the 39-year history of U.S.B.R. and U.S.G.S. water quality monitoring on Lake Powell, we have begun to demonstrate the effect of dam operations and other factors on the water quality and hydrodynamics of Lake Powell. Extensive historical records and ongoing monitoring and research demonstrate the effects of dam operational anomalies induced from variations in climate and/or policy, including emergency flood releases in the 1980s, interim flows of the early 1990s, the 1996 experimental flow; as well as the climatic effects of both flood and drought years. No special data were collected to answer the question, but rather, the stock of existing data was analyzed to provide the answers and to fuel the questions that formed the assessment. The results show that, combined with other influences, dam operations have an undeniable effect upon the stratification and mixing of the reservoir, and those effects are passed downstream through the dam. The ‘96 experimental flood demonstrated the effects of using alternate structures for the release of water, in this case, the hollow jet tubes that are positioned 100 feet below the penstock withdrawal ports. The historic record of the 1980s indicated that the combination of high and repeated spring floods and high and sustained discharge from penstocks as well as spillways and hollow jet tubes caused substantial mixing of the reservoir.

Living in Paradise: the Kanab Ambersnail in Grand Canyon

Clay B. Nelson, Jeff A. Sorensen, Arizona Game and Fish Department

Abstract. The endangered Kanab ambersnail (Succineidae: *Oxyloma haydeni kanabensis*) is a terrestrial snail that occurs at only two locations in the American Southwest. The Arizona population resides at a riverside spring called Vasey's Paradise, in Grand Canyon National Park. This population is threatened by habitat loss from high flows released from Glen Canyon Dam. However, increased flows such as "Beach/Habitat Building Flows" are used as a management tool to enhance beaches and backwater habitat throughout the river corridor, mimicking natural ecosystem processes. As a result, the Vasey's Paradise population has become the center of an intensive interagency effort focused on research, monitoring, and species recovery. Since 1995, the Arizona Game and Fish Department has partnered with various federal, state, university, and non-governmental organizations to study and further conservation goals for this rare mollusk. No additional populations of Kanab ambersnail have been discovered during habitat surveys of the Colorado Plateau. In 1998, seed populations of Vasey's Paradise snails were translocated to three other sites along the Colorado River corridor. One of those translocated populations, at Upper Elves Chasm, has become established and continues to show successful recruitment and expansion of occupied habitat. This new secondary population will help mitigate incidental take issues at Vasey's Paradise in future experimental flows and further adaptive management strategies for the Colorado River ecosystem.

NPS River Corridor Cultural Monitoring and Remedial Action Program

Lisa Leap, Jennifer Dierker, Nancy Andrews, National Park Service, Flagstaff, AZ

Abstract. NPS archaeologists monitor cultural resources for the Glen Canyon Dam's Adaptive Management Program through a Programmatic Agreement on Cultural Resources. This long-term monitoring program has been in place since 1992 and is the primary means of assessing the condition of cultural resources downstream of Glen Canyon Dam. Periodically, monitors discover newly exposed cultural features or cultural sites. Given the erosive nature of the inner canyon environment, it is no surprise that new discoveries occur. However, depletion of sediment in the Colorado River system coupled with the absence of cyclical flooding of alluvial terraces is exacerbating the erosive situation. The operation and existence of Glen Canyon Dam directly, indirectly and potentially effects the condition of downstream cultural properties. Since 1992, more than 100 previously unknown features or diagnostic artifacts have been identified by cultural monitors at over 60 archaeological sites and Traditional Cultural Properties. These discoveries are important, and add to the limited body of knowledge on Grand Canyon history and prehistory. Long-term monitoring is a useful tool for detecting change in this dynamic environment.

Seasonal Light Variation in a Canyon-bound River: Potential Effects on Distribution, Growth and Colonization of Photoautotrophs

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Abstract. Vertical relief interferes with incoming solar incidence and can dramatically affect ecosystem energetics, particularly in canyon-bound regions or along densely vegetated streams. Physical obstructions are recognized for having pronounced effects on daily, seasonal, and annual solar insolation levels, such that subtle differences in altitude angles, elevation surface gradients, viewshed, and orientation generate varying levels of spatio/temporal complexity. Mean annual daily insolation levels system-wide were estimated to be 36 mol m^{-2} d^{-1} (17.5 std), and varied seasonally from 13.4 – 57.4 mol m^{-2} d^{-1}, for winter and summer, respectively. In comparison, mean daily insolation for environmental conditions lacking topographic effect (idealized plane) were reduced by 22% during summer, and as much as 53% during winter. Also, depending on outlying topography, canyon bound regions having east-west (EW) orientations had higher seasonal variation, averaging from 8.1 – 61.4 mol m^{-2} d^{-1}, for winter and summer, respectively. For EW orientations, 70% of mid-channel sites were obscured from direct incidence during part of the year; and of these sites, average diffuse light conditions persisted for 19.3% of the year (70.5-d), and extended upwards to 194-d. Light-depth limitation should be most evident for EW oriented channels having high elevation angles. We would expect to observe decreased primary production during winter, and alternately higher production and standing biomass during summer periods when these same channel orientations receive considerably more solar incidence. There is some evidence for this phytobenthic pattern; however, the vertical distribution is further compounded by differences in optical properties throughout the Colorado River. Turbidity has been recognized as increasing with downstream distance. Patterns of daily solar insolation correspond to total radiation transmission, and probably explain some of the distribution and flowering patterns of xeric and riparian vegetation in the deep canyon ecosystem.

Translocation of Humpback Chub (*Gila cypha*) Above Chute Falls, Little Colorado River

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Abstract. On August 1, 2003, the Arizona Fishery Resources Office, along with personnel from the Arizona Game and Fish Department and Northern Arizona University, released 283 humpback chub (HBC) into the Little Colorado River (LCR), above Chute Falls, near river kilometer 16.2. This action was part of the December 6, 2002, Biological Opinion on the proposed experimental releases from Glen Canyon Dam and removal of nonnative fish. As a conservation measure for this project, the U.S. Bureau of Reclamation, Grand Canyon Monitoring and Research Center and the National Park Service agreed to relocate approximately 300, 50-100 mm HBC to upstream areas of the LCR in an attempt to increase survivorship of HBC. It is hoped that this translocation will increase younger HBC that recruit to adulthood by allowing them an opportunity to exploit the high food resources, warmer water temperatures, and reduced competition/predation by fewer large-bodied fishes that are associated with this area. If this experiment is successful, it will supply a viable action to expand suitable HBC rearing habitats within the LCR and may bide additional time until other successful recovery actions can be implemented in the Colorado River or one of its tributaries. HBC were captured via baited hoop nets and seining near the confluence of the Colorado River. All translocated fish were implanted with a yellow elastomer tag near the dorsal fin insertion on the left side to identify them from downstream populations. Fish were transported upstream via helicopter and were on 3 liters/minute of oxygen during transport. Due to high CO_2 levels above Chute Falls (220 mg/L) as compared to downstream areas (83 mg/L), it took nearly 5 hours to temper the chubs to the water conditions above Chute Falls. After tempering was complete, fish were transferred to live cars in the river and monitored for an additional 17 hours before release. Fish were observed feeding and dispersing into downstream habitats in search of cover post-release. Surveys will commence in November 2003 to determine retention above Chute Falls.

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Cultural Resource Treatment Options Discussion
October 29, 2003 – 7:30-9:30 p.m.

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Acronyms

AEAM	Adaptive Environmental Assessment and Management
AMP	Glen Canyon Dam Adaptive Management Program
AMWG	Adaptive Management Work Group
BHBF	Beach/Habitat-Building Flow (1996 GCD “Spike” Flow experiment)
BNT	Brown Trout
CPE	Catch Per Effort
CPUE	Catch Per Unit Effort
CR	Colorado River (through Grand Canyon)
CRE	Colorado River Ecosystem
DTM	Digital Terrain Model
EA	Environmental Assessment
EIS	Environmental Impact Statement
FIST	Fine-grained Integrated Sediment Team
FMS	Flannelmouth Sucker (species of concern native Arizona fish)
GCD	Glen Canyon Dam
GCD AMP	Glen Canyon Dam Adaptive Management Program
GCES	Glen Canyon Environmental Studies (predecessor to GCMRC)
GCMRC	Grand Canyon Monitoring and Research Center (Flagstaff, Arizona)
GCNP	Grand Canyon National Park
GIS	Geographic Information System
GPS	Global Positioning System
HBC	Humpback chub (endangered native Arizona fish)
HMF	Habitat Maintenance Flow (Fall 2000 flow experiment)
KAS	Kanab Ambersnail (endangered snail species)
IRP	Independent Review Panel
KCFS	(thousand) cubic feet per second
LCR	Little Colorado River
LIDAR	Light Detection And Ranging
LSSF	Low Summer Steady Flows (experiment conducted in Water Year 2000)

MLFF	Modified Low Fluctuating Flows (defined in GCD EIS)
NAU	Northern Arizona University (Flagstaff, Arizona)
NPS	National Park Service
PIT	Passive Integrated Transponder
PPC	Power Plant Capacity (dam flow)
RBT	Rainbow Trout
RM	River Mile
RKM	River Kilometer
SBSC	USGS Southwest Biological Science Center (Flagstaff, Arizona)
SWCA	SWCA Environmental Consultants
TCD	Temperature Control Device
TL	Total Length
TWG	Technical Work Group
USBR	United Stated Bureau of Reclamation
USGS	United States Geological Survey
USGS-BRD	U.S. Geological Survey Biological Resources Discipline
USGS-GD	U.S. Geological Survey Geologic Discipline
USGS-WRD	U.S. Geological Survey Water Resources Discipline
YOY	Young-of-year (age of fish)