Glen Canyon Dam Adaptive Management Work Group
Agenda Item Information
December 5-6, 2006

Agenda Item

Grand Canyon Monitoring and Research Center Completed Science Projects and Reports – Executive Summary

Action Requested

√ Information item only; no action is requested. If further action in any of these areas is deemed desirable by AMWG, specific direction can be given to TWG for follow up.

Presenters

Ted Melis, Deputy Chief, Grand Canyon Monitoring and Research Center
Matthew Andersen, Biological Resources Program Manager, Grand Canyon Monitoring and Research Center

Previous Action Taken

√ By AMWG:
All of the projects reported on herein were recommended by AMWG to the Secretary of the Interior to be included in the GCMRC workplan in earlier years.

- The HBC fact sheet addresses the first priority question approved by AMWG at the August 2004 priority-setting workshop. The two-part question is, "Why are the Humpback chub not thriving, and what can we do about it? How many Humpback chub are there and how are they doing?"
- The genetics report was part of the Humpback chub action plan approved by AMWG in 2002.
- The sediment augmentation feasibility study was recommended by the HBC Ad Hoc Group and included in the GCMRC budget that was recommended to the Secretary of the Interior by AMWG.
- The Fine Integrated Sediment Team Research and Development Project and the Sediment Transport Model Development Project were efforts recommended to the Secretary by AMWG for research and development on methods for sand storage monitoring.

Relevant Science

√ The following describes the relevant research or monitoring on this subject: The relevant science is presented below.

Background Information

The Grand Canyon Monitoring and Research Center wishes to report to AMWG on completed science projects and reports, as follows:

Humpback chub fact sheet – Please see the attached two-page fact sheet.

Genetics Report - An analysis of the population genetics of Gila species (humpback chub, roundtail chub, and bonytail), with special emphasis on the Grand Canyon humpback chub population, was contracted by the GCDAMP through GCMRC. The analysis was conducted by Drs. Marlis Douglas and Michael Douglas of Colorado State University. GCMRC is currently reviewing the second iteration of this document (received September 2006). The analysis indicates that Grand Canyon (Little Colorado River) humpback chub are a unique population that is distinguishable at the molecular level from five other humpback chub populations, the latter found in the upper Colorado River basin. One of the distinguishing characteristics of Grand Canyon humpback chub is the relatively high degree of hybridization with roundtail chub, possibly due to much drier, more limited conditions at the end of the Pleistocene. A small amount of hybridization between humpback chub and bonytail was also observed. Despite some observed hybridization, the authors still conclude that humpback chub, roundtail chub, and bonytail remain distinct species. The number of humpback chub from Marble Canyon (30 mile) available for this study was low, so additional study that includes more Marble Canyon humpback chub may be warranted. Analysis of the few Marble Canyon fish suggests that they may have a close relationship to the humpback chub from further upstream in Desolation Canyon.

Sediment Augmentation Feasibility Study – The sediment augmentation feasibility study was funded through annual work plans and budgets recommended by AMWG in 2004 and 2005. The study was completed in summer 2006, and the report is set to be finalized in December 2006. This study was associated with humpback chub comprehensive planning and is related to GCDAMP Goal #2. The report by Randle et al. has been peer reviewed and finds that importation of sand and finer sediment from Lake Powell sources (specifically, Navajo Creek) is feasible with modern engineering technologies and designs. Fine sediment might be imported to achieve levels of turbidity below Glen Canyon Dam to provide cover for native fishes, along with sand in sufficient volumes to substantially augment sand supply for beach restoration (sand supply about equivalent to the annually supply from the Paria River). Alternatively, either sand or fine sediment could be imported separately under varied designs. A total of five design options are described in the report with injection points for the sediment either in Upper Glen Canyon or near Lees Ferry. The sediment supply of Navajo Creek was assessed by USGS (Denver laboratory) for contaminants. No contamination was found and the authors concluded that the deltaic deposits might be utilized to augment sediment supplies below the dam for several decades if the system were eventually built and annually operated. Appraisal cost estimates for the five designs range from about 110 to 400 million dollars, with annual operating costs of around 10 million dollars. Several recommendations are included in the report as next steps for managers to consider. The Technical Work Group has been briefed by the lead author on the results of this study. The TWG will review the final report and develop a recommendation for AMWG.

Sediment Transport Model Development Project - Over the past four years, a collaborative effort between researchers at the USGS, Johns Hopkins University, and Utah State University has been directed toward the development of predictive models of sand transport, erosion, and deposition along the Colorado River below Glen Canyon Dam. Two types of models have developed: 1) a multi-dimensional (2D) model of transport processes within individual eddies and/or short reaches, and 2) a quasi-one-dimensional (1D) model of sand transport for the entire system between Lees Ferry and Phantom Ranch. The 1D model uses information derived from the 2D model in a novel approach to account for the exchange of sand between the main channel and eddies. The primary application envisioned for the 2D model is to evaluate the responses of

individual eddies to experimental flows, such as BHBFs. The primary application envisioned for the 1D model is to track and predict the fate of tributary sand inputs as they move through the system under various flow regimes. The 2D model was previously published and the 1D model has been recently published in Water Resources Research. Based on the sediment Protocol Evaluation Panel (PEP) review in August 2006, further calibration and validation of the 1D model is being conducted. Also, the PEP has recommended further review of the 1D model once the additional calibration and validation has been completed; this review is planned for mid-year FY07. The project report was accepted as final by the GCMRC in summer 2006 and is available (Wiele et al., 2006) through the GCMRC web sites: www.gcmrc.gov. This research and development project was recommended by AMWG under annual work plans and budgets during FY 2002-2005 and the effort is generally related to GCDAMP Goals #7 and #8 (suspended-sediment transport as a component of downstream quality of water, and sand resources).

Fine Integrated Sediment Team (FIST) Research And Development Project – The FIST project completed reach-based fieldwork in 2002, 2004, and before and after the November 2004 BHBF test, and completed campsite/sandbar surveys in 2001, 2002, 2003, 2004, and 2005. Data from these field efforts have been processed, finalized, and delivered to the GCMRC. Preliminary results from the FIST project have been presented at the following professional scientific meetings: 2003 Geological Society of America Annual Meeting (published abstract); 2004 American Geophysical Union Fall Meeting (2 published abstracts); 2005 Geological Society of America Annual Meeting (published abstract); 2005 American Geophysical Union Fall Meeting (3 published abstracts); 8th Federal Inter-Agency Sedimentation Conference, Reno, Nevada, April 2-6, 2006 (published proceedings article). The project is now in its final stages with articles being prepared for publication. Data and methods reports will be finalized this fall. Interpretive reports will be finalized during the winter/spring of 2007. Final presentations, with recommendations for future monitoring, will be made to the TWG during the winter/spring of 2007. Findings will be evaluated by the GCMRC and used to develop a report on long-term monitoring recommendations that will be submitted to the TWG for consideration and use in ongoing planning related to monitoring. This research and development project relates directly to GCDAMP Goal #8 (sediment resources).

Sediment PEP Final Report (SEDS-PEP III) – A review panel meeting was convened in August 2006 by the GCMRC to finalize evaluation of research and development efforts for monitoring of sediment resources. This review effort generally relates to GCDAMP Goals #7 and #8 (quality of water with respect to suspended sediment and sand resources). The panel's final report was completed in early October 2006 and distributed to the Technical Workgroup for consideration. Dr. Ellen Wohl, Science Advisor for geomorphology and sediment, chaired the review panel and was lead author on the final report. Dr. Wohl presented the findings of the panel to the Technical Workgroup at their November 2006 meeting. The final report is available online through the GCMRC's web page: www.gcmrc.gov. The GCMRC is preparing a report with recommendations for monitoring of sediment resources on the basis of recent research reports, the SEDS-PEP III review and the GCDAMP strategic plan. This report will be submitted to the Technical Workgroup in late winter or early spring for their consideration and use in ongoing planning efforts related to monitoring (as per the protocols described in the GCMRC's draft Monitoring and Research Plan for 2007-2011).

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Grand Canyon Humpback Chub Population Stabilizing

The humpback chub (*Gila cypha*) (fig. 1) is a long-lived, freshwater fish found only in the Colorado River Basin. To survive in the famously turbulent Colorado River, the species developed some unusual adaptations, including a large adult body size, large predorsal hump, and small eyes. A number of factors have contributed to the decline of humpback chub and other native Colorado River fish. In 1967, the humpback chub was added to the federal list of endangered species and is today protected under the Endangered Species Act of 1973. Only six populations of humpback chub are currently known to exist, five in the Colorado River Basin above Lees Ferry, Arizona, and one in Grand Canyon, Arizona.

Monitoring and research of the Grand Canyon population of humpback chub is overseen by the U.S. Geological Survey's Grand Canyon Monitoring and Research Center (GCMRC) under the auspices of the Glen Canyon Dam Adaptive Management Program (GCDAMP). Recently collected data indicate that the number of adult (age-4+) humpback chub in Grand Canyon stabilized between 2001 and 2005 after more than a decade of decline.

Figure 1. The humpback chub (*Gila cypha*) is an endangered freshwater fish found only in the Colorado River Basin. Recently collected data indicate that the number of adult fish (age-4+) in Grand Canyon stabilized between 2001 and 2005 after years of decline (photograph courtesy of George Andrejko, Arizona Game and Fish Department).

Background

The majority of Grand Canyon humpback chub are found in the Little Colorado River (the largest tributary to the Colorado River in Grand Canyon) and the Colorado River near its confluence with the Little Colorado River. Small numbers of humpback chub are found elsewhere in Grand Canyon, but successful reproduction has only been documented for those fish found in or near the Little Colorado River.

Reproduction has been restricted to the Little Colorado River because of changes in the mainstem Colorado River after the completion of Glen Canyon Dam. For example, prior to the dam, the water temperature of the Colorado River fluctuated seasonally from 0ºC to 29ºC (30–80ºF). Today, because the release structures of the dam are well below the surface of Lake Powell, the water that leaves the dam is cold, with an average temperature of 8ºC (46ºF). Water temperatures in the main channel of the Colorado River have been too cold for humpback chub to successfully reproduce except near the Little Colorado River.

Recent Findings

Since scientists began monitoring efforts in 1989, the population of adult humpback chub in Grand Canyon has declined steadily until recently (fig. 2.). The death of 15% to 20% of adult fish each year and a low rate of juvenile fish surviving into adulthood contributed to the decline. Adult mortality rates and the failure of juvenile fish to reach adulthood have both been attributed to changes in Little Colorado River and Colorado River hydrology, the weakening of young fish by the nonnative Asian tapeworm (*Bothriocephalus acheilognathi*), and competition with and predation by nonnative fish species.

Between 2001 and 2005, however, conditions appear to have improved and the number of adult fish stabilized at an estimated 5,000 fish (fig. 2). Additionally, near the confluence of the Colorado and Little Colorado Rivers, catch-rate data from the monitoring program indicate an increased abundance of juvenile humpback chub between 2003 and 2005. Increases in juvenile fish during the same period were also apparent for other native species found near the confluence, including bluehead sucker (*Catostomus discobolus*), flannelmouth sucker (*Catostomus latipinnis*), and speckled dace (*Rhinichthys osculus*).

Elsewhere in Grand Canyon, catch rates for humpback chub produced in 2005 were higher than previous years in middle and lower Marble Canyon (U.S. Geological Survey, unpub. data, 2006). Higher than average catch rates at these locations were unexpected because they are up to 25 river miles above the confluence of the Colorado and Little Colorado Rivers where spawning usually occurs. These findings suggest that more favorable conditions for spawning and incubation existed in the Colorado River main channel during 2005.

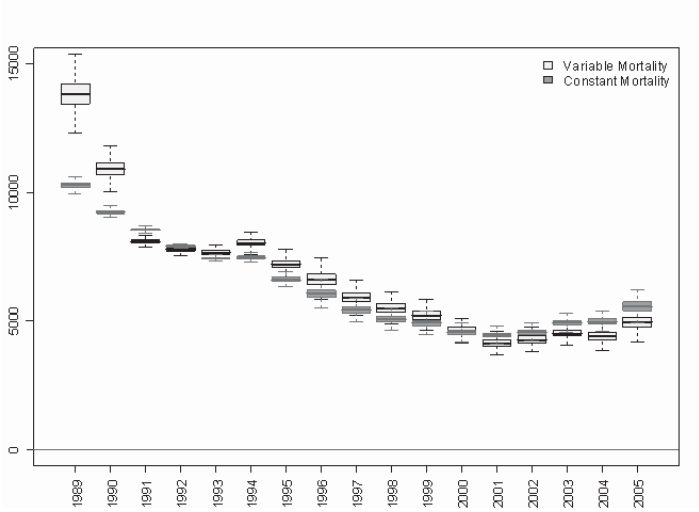

Figure 2. Adult (age-4+) humpback chub population estimates (1989–2005) for the Little Colorado River. Upper and lower bounds are 95% Bayesian credible intervals. When confidence intervals are considered, the model indicates that the population has stabilized.

Discussion

The exact causes of the stabilization of the adult population and increased numbers of young humpback chub cannot be specified at this time. However, humpback chub in Grand Canyon are thought to have benefited from several changes, including the experimental removal of nonnative fish, experimental water releases, and drought-induced warming.

Beginning in 2003, large numbers of rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) were removed from the area near the confluence of the Colorado and Little Colorado Rivers. Rainbow and brown trout are thought to compete with humpback chub for food and prey on young fish. Since 2003, the rainbow trout population in the Colorado River near the Little Colorado River has been reduced by more than 60%. The removal effort will continue through 2006.

Humpback chub produced in 1999 may also have benefited from substantial in-stream warming as the result of the 2000 low summer steady flow experiment. The experiment held Glen Canyon Dam releases constant at 8,000 cubic feet per second from June through August 2000 and included two habitat maintenance flows (high, steady dam releases). As a result, in the summer of 2000, peak water temperatures in some parts of Grand Canyon exceeded 20ºC (68.5ºF), which represents a temperature increase when compared with typical peak temperatures of 15–18ºC (59–64ºF) in recent years. Humpback chub habitat may also have been improved as the result of experimental floods conducted in 1996, 1997, 2000, and 2004.

Since 2003, water temperatures below the dam have also increased as the result of drought conditions. As drought has reduced flows into Lake Powell, the level of the reservoir has dropped, allowing warmer water found closer to the surface of the reservoir to reach the release structures. In 2005, water temperatures in the mainstem Colorado River near the Little Colorado River exceeded 17ºC (60.8ºF), the warmest temperatures recorded since the reservoir filled in 1980 and approximately the minimum temperature needed by humpback chub to successfully reproduce. Native fish are thought to benefit from warmer water releases; however, there is great concern that warmer water temperatures may also benefit nonnative warmwater fish like the channel catfish (*Ictalurus punctatus*), a voracious predator.

Scientists are not yet able to determine the relative importance of the various factors that may be contributing to recent improvements. More work will be required to understand how nonnative fish, temperature, and the operation of Glen Canyon Dam interact to affect the humpback chub population in Grand Canyon.

The Glen Canyon Dam Adaptive Management Program was established to monitor and analyze the effects of dam operations on downstream resources and to use these assessments to recommend to the Secretary of the Interior adjustments intended to improve the values for which the Glen Canyon National Recreation Area and Grand Canyon National Park were established. Fieldwork related to humpback chub research was conducted cooperatively by GCMRC and GCDAMP partners, including the Arizona Game and Fish Department and the U.S. Fish and Wildlife Service.

References

Coggins, L.G., Pine, W.E., III, Walters, C.J., Van Haverbeke, D.R., Ward, D., Johnstone, H.C., 2006, Abundance trends and status of the Little Colorado River population of humpback chub: North American Journal of Fisheries Management, v. 26, p. 233–245.

Gloss, S.P., and Coggins, L.G., 2005, Fishes of Grand Canyon in Gloss, S.P., Lovich, J.E., and Melis, T.S., eds., 2005, The state of the Colorado River ecosystem in Grand Canyon: U.S. Geological Survey Circular 1282, 220 p.

Melis, T.S., Martell, S.J.D., Coggins, L.G., Pine, W.E., III, and Andersen, M.E., 2006, Adaptive management of the Colorado River ecosystem below Glen Canyon Dam, Arizona: using science and modeling to resolve uncertainty in river management, in Specialty Summer Conference on Adaptive Management of Water Resources, Missoula, Mont., 2006, CD-ROM Proceedings (ISBN 1-882132-71-8): Middleburg, Va., American Water Resources Association.

Paukert, C.P., Coggins, L.G., and Flaccus, C.E., 2006, Distribution and movement of humpback chub in the Colorado River, Grand Canyon, based on recaptures: Transactions of the American Fisheries Society, v. 135, p. 539–544.

More Information

Matthew E. Andersen
U.S. Geological Survey
Southwest Biological Science Center
Grand Canyon Monitoring and Research Center
2255 N. Gemini Drive
Flagstaff, Arizona, 86001
Tel: 928-556-7094
E-mail: mandersen@usgs.gov
Website: www.gcmrc.gov

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Completed Science Projects 2006

Southwest Biological Science Center
Grand Canyon Monitoring and Research Center
Adaptive Management Workgroup Meeting
December 5 and 6, 2006

U.S. Department of the Interior
U.S. Geological Survey

Presentation Outline

- Humpback Chub Population update
- Humpback Chub Genetics report
- Sediment Transport Model Development
- FIST (R&D on Sand Storage Monitoring)
- Protocol Evaluation Panel (PEP) - Sediment
- Sediment Augmentation Feasibility Study

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Humpback Chub Population

- Age-Structured Mark-Recapture (ASMR) is an appropriate open model for estimating capture probabilities, survival, abundance, and recruitment of fishes (Coggins et al. 2006a)
- Method is well suited to sparse, long-term mark recapture data

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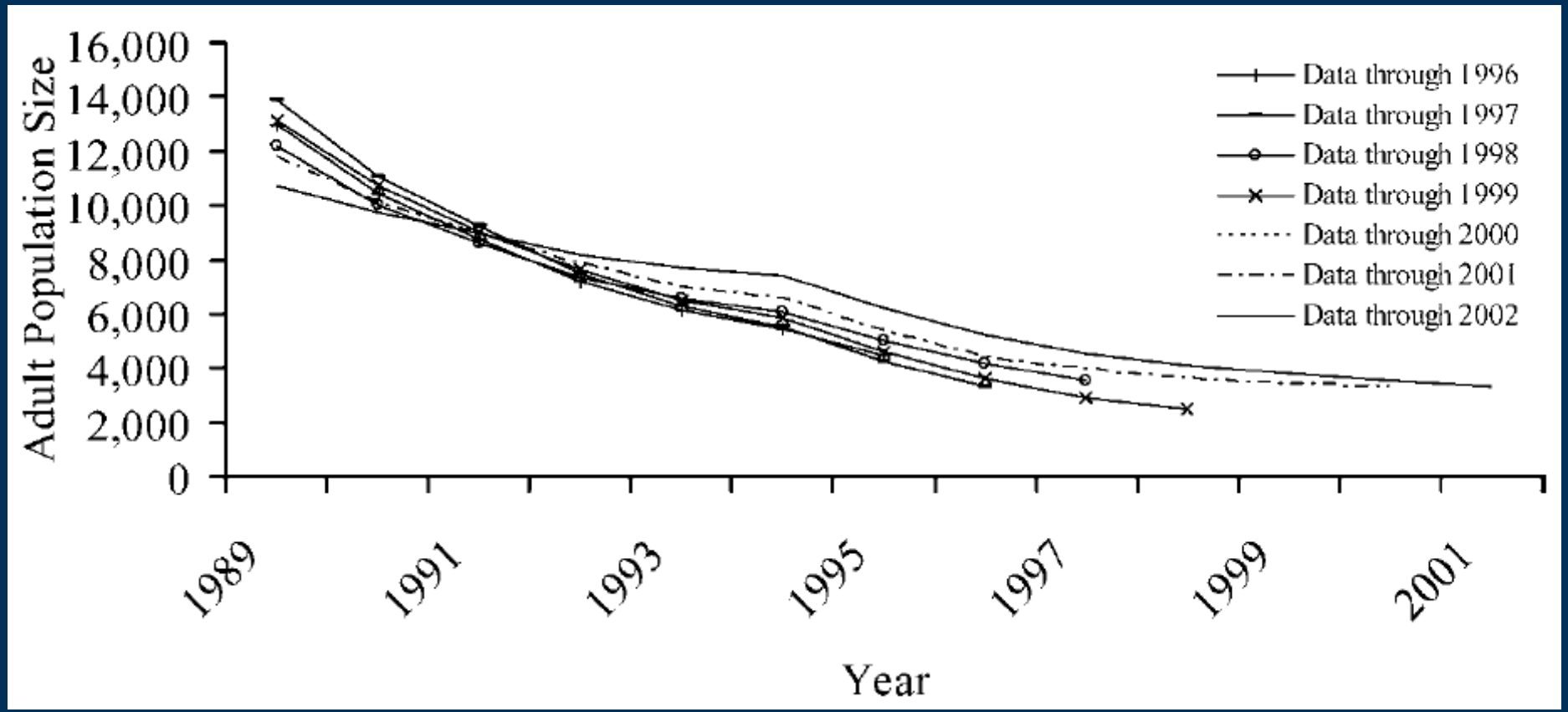
ASMR model results dependent on year of data (Coggins et al. 2006b)



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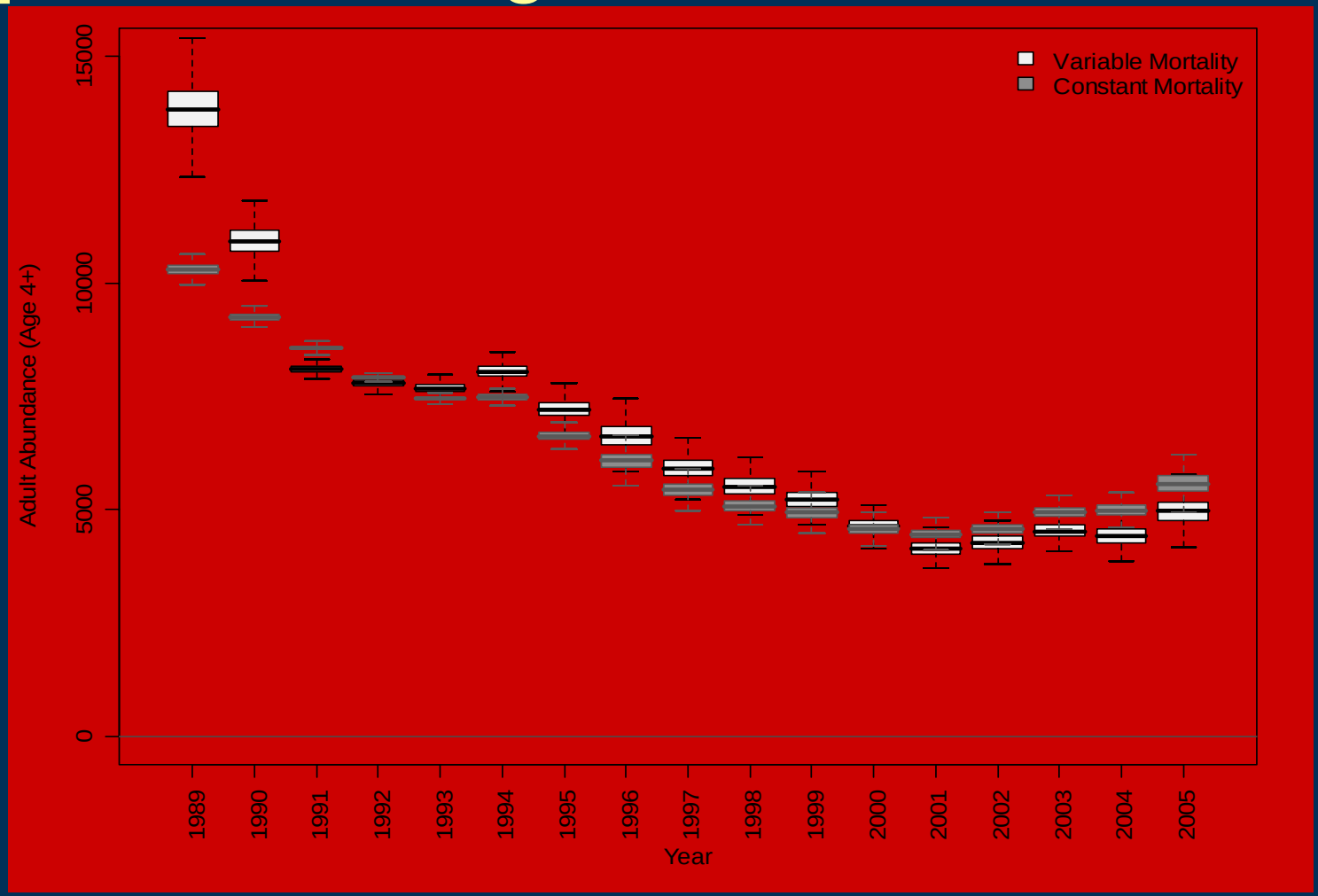
ASMR Models of GC Adult (4+ yrs.) HBC Population through 2005



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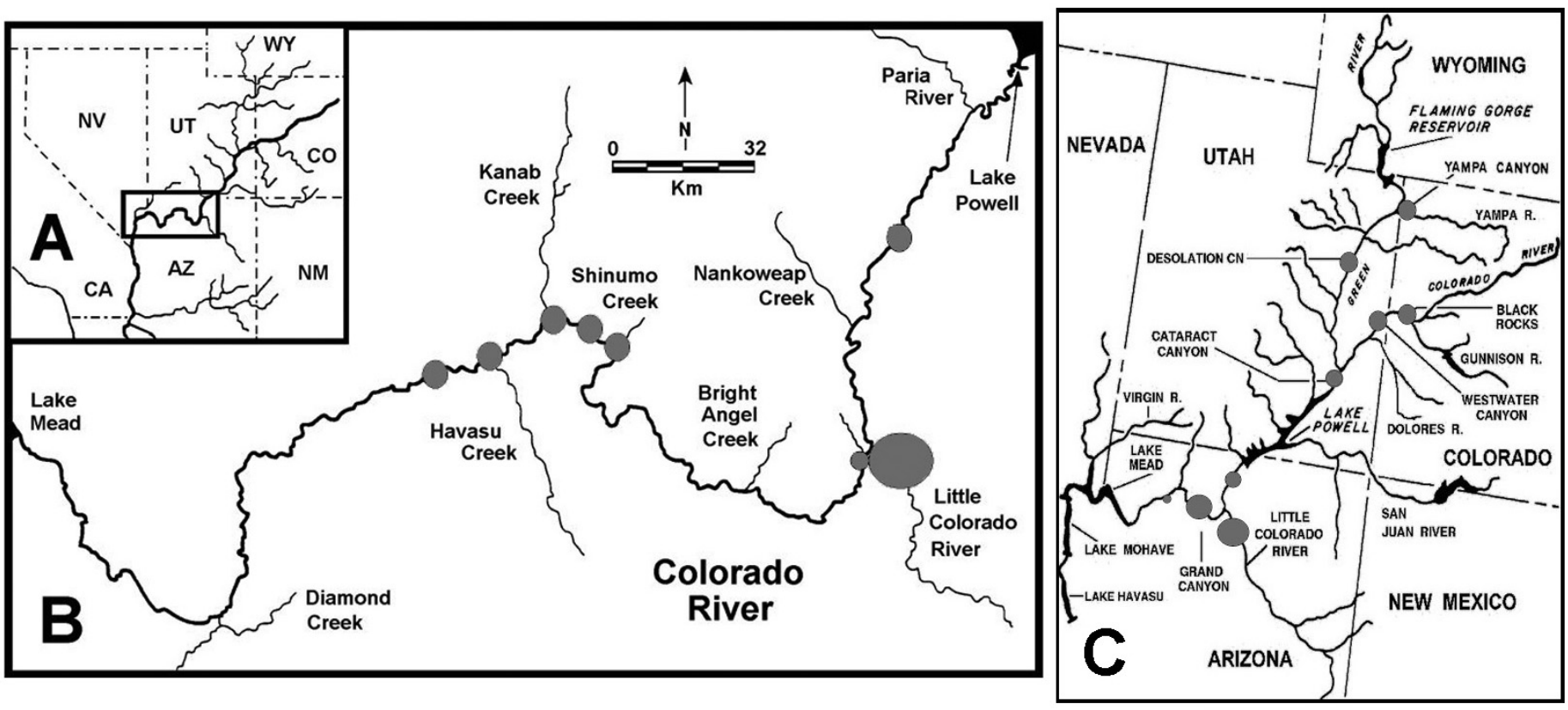
Humpback Chub Genetics Report
Sample Locations



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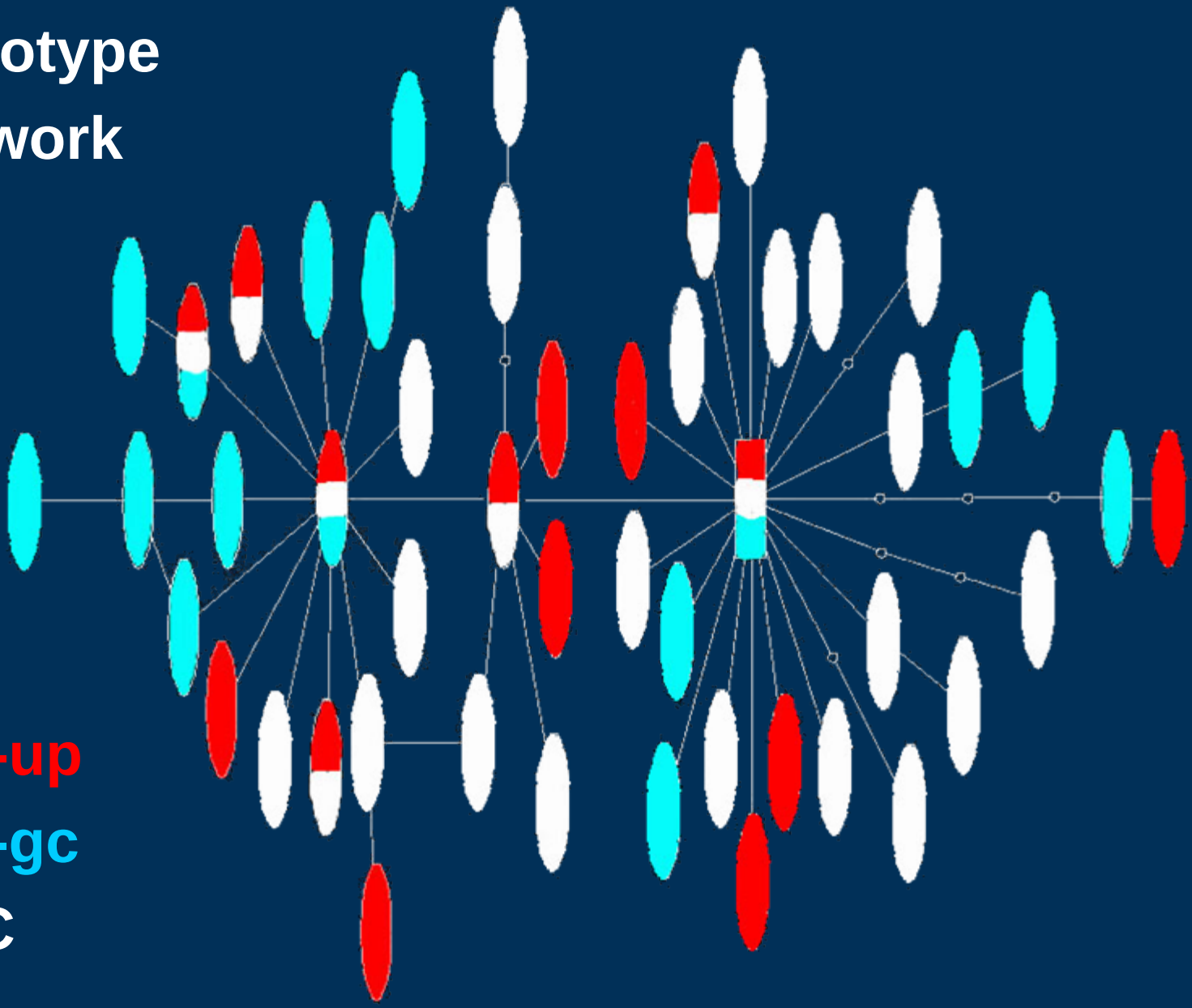
Haplotype Network



HBC-up

HBC-gc

RTC

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Humpback Chub Genetics Report (Draft; Douglas and Douglas, 2006)

- **Grand Canyon humpback chub are unique**, distinguishable from other humpback chub in Colorado River Basin
- Humpback chub, roundtail chub, and bonytail are all closely related
- Six Management Units indicated

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SEDIMENT
Sediment Related Project Updates 2001-2006

U.S. Department of the Interior
U.S. Geological Survey

Sediment Transport Model Development – Part I "Main Channel"

- Final Report by Wiele and others July 2006
- 1-D Sand Transport Model w/ Unsteady Flow
- Short-Term Prediction of Fate of Sand Inputs
- Model Calibration/Evaluation Ongoing Now
- Modeling Review Workshop in winter 2007

Findings: 1) progress has been made in development of sand transport modeling; 2) PEP review identified need for additional development tasks to obtain better, longer-term predictive capabilities; 3) Modeling review workshop needed to advance the ongoing development of this model.

Suggested Next Step: Final report and presentation to TWG and sediment ad hoc in 2007 for consideration and recommendations back to AMWG – needs for future work?

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Sediment Transport Model Development – Part II "Little Colorado River"

- Final Report by Topping expected in Dec 2006
- Analysis of all historical flow and sediment-transport data
- Objective - Prediction of Sand & Fine Sediment Inputs
- Model Calibration/Evaluation Ongoing Now
- Approach Similar to Paria River Model (already being used)

Findings: 1) progress has been made since 1990 in modeling sand production from the two major, downstream tributaries; 2) both the Paria and LCR models were used to estimate recent sand inputs to the main channel and continue to support experimental research and monitoring needs of the GCD-AMP

Suggested Next Step: Final report and presentation to TWG and sediment ad hoc in 2007 for consideration and recommendations back to AMWG

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R&D on Sand Storage Monitoring (FIST)

- Draft Reports by Rubin and others Expected in Dec 2006
- Analysis of Existing and "New" Sand Monitoring Methods
- Objective – Provide Experimental and Monitoring Support & Recommendations for Long-Term Sand Storage Monitoring
- Integration of Ground-Based and Airborne Technologies
- Identify Options for Sand Storage Data that Meet Needs of Managers

Findings: 1) the 2004 high-flow test provided excellent opportunity for this R&D project to test new monitoring methods; 2) Testing of multi-beam hydro-acoustics, airborne digital imagery and LiDAR have been extensive, but recommendations on future use for monitoring are still pending; 3) there are many combinations of monitoring options to be considered by both managers and scientists for use in monitoring sand storage changes (and related habitats, such as backwaters, campsites and archeological preservation areas)

Suggested Next Step: Final report and presentation to TWG and sediment ad hoc in 2007 for consideration and recommendations on long-term monitoring back to AMWG

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Protocol Evaluation Panel (PEP) - Sediment

- Final Report by Wohl and others delivered in Oct 2006
- Evaluated R&D for Sediment and Flow Monitoring
- Objective – Provide Input on Sediment Long-Term Monitoring
- Evaluated Sediment Modeling Development and Progress
- Third and Final SED-PEP Review Meeting since 1998

Findings: 1) support for new sediment mass-balance methods; 2) concerns about status of sand transport model results in the main channel; 3) recommendation for modeling review workshop in 2007; partial recommendations for sand storage monitoring, pending completion of FIST reporting

Suggested Next Steps: 1) Convene modeling review workshop in 2007, 2) As per MRP, integrate PEP recommendations into Monitoring Evaluation Report and presentation to TWG and sediment ad hoc in spring 2007 for consideration as Long-Term Monitoring Plan is developed

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Sediment Augmentation Feasibility Study

- Randle and others report peer reviewed in October
- Reviews sent to authors in November
- Final report expected in early 2007

Findings: 1) It is technically feasible to do this; 2) five design options were identified for transporting sediment from Navajo Creek to below GCD; 3) construction costs estimated at between ~100 to 400 million dollars; 4) several additional steps are recommended if project is to move to next planning phase toward implementation

Suggested Next Step: Final report and presentation to TWG and sediment ad hoc in 2007 for consideration and recommendations back to AMWG

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Results of the 2003–06 GCDAMP Experiment: Publications, Abstracts, Professional Meetings, and Presentations

Finalized Reports and Published Papers

Draut, A.E., and Rubin, D.M., 2005, Measurements of wind, aeolian sand transport, and precipitation in the Colorado River corridor, Grand Canyon, Arizona – November 2003 to December 2004: U.S. Geological Survey Open-File Report 2005-1309, 70 p., http://pubs.usgs.gov/of/2005/1309/.

Draut, A.E., and Rubin, D.M., 2006, Measurements of wind, aeolian sand transport, and precipitation in the Colorado River corridor, Grand Canyon, Arizona – January 2005 to January 2006: U.S. Geological Survey Open-File Report 2006-1188, 88 p., http://pubs.usgs.gov/of/2006/1188/.

Grams, P.E., 2006, Sand transport over a coarse and immobile bed: Baltimore, Johns Hopkins University, unpublished Ph.D. dissertation, 177 p.

Korman, J., Kaplinski, M., Hazel, J.E. III, and Melis, T.S., 2005, Effects of the experimental fluctuating flows from Glen Canyon Dam in 2003 and 2004 on the early life history stages of rainbow trout in the Colorado River: Final report, cooperative agreement no. 04WRAG0006, modification no. 002, 183 p., http://www.gcmrc.gov/library/reports/biological/Fish_studies/Ecometric/Korman2005.pdf.

Melis, T.S., Martell, S.J.D., Coggins, L.G., Pine, W.E., III, and Andersen, M.E., 2006, Adaptive management of the Colorado River ecosystem below Glen Canyon Dam, Arizona: using science and modeling to resolve uncertainty in river management, *in* Specialty Summer Conference on Adaptive Management of Water Resources, Missoula, Mont., 2006, CD-ROM Proceedings (ISBN 1-882132-71-8): Middleburg, Va., American Water Resources Association.

Speas, D.W., Walters, C.J., Ward, D.L., Rogers, S.R., 2004, Effects of intraspecific density and environmental variables on electrofishing catchability of brown and rainbow trout in the Colorado River: Phoenix, Ariz., Arizona Game and Fish Department Research Branch.

Rubin, D.M., Chezar, H., Harney, J.N., Topping, D.J., Melis, T.S., and Sherwood, C.R., 2006, Underwater microscope for measuring spatial and temporal changes in bed-sediment grain size: U.S. Geological Survey Open-File Report 2006-1360, http://pubs.usgs.gov/of/2006/1360/.

Topping, D.J., Rubin, D.M., Schmidt, J.C., Hazel, J.E., Jr., Melis, T.S., Wright, S.A., Kaplinski, M., Draut, A.E., and Breedlove, M.J., 2006, Comparison of sediment-transport and bar-response results from the 1996 and 2004 controlled-flood experiments on the Colorado River in Grand Canyon, *in* Federal Inter-Agency Sedimentation Conference, 8th, Reno, Nevada, 2006,CD-ROM Proceedings (ISBN 0-9779007-1-1).

Topping, D.J., Wright, S.A., Melis, T.S., and Rubin, D.M., 2006, High-resolution monitoring of suspended-sediment concentration and grain size in the Colorado River using laser-diffraction instruments and a three-frequency acoustic system, *in* Federal Inter-Agency Sedimentation Conference, 8th, Reno, Nevada, 2006,CD-ROM Proceedings (ISBN 0-9779007-1-1).

Wright, S.A., and Gartner, J.W., 2006, Measurements of velocity profiles and suspended sediment concentrations in a Colorado River eddy during high flow, *in* Federal Inter-Agency Sedimentation Conference, 8th, Reno, Nevada, 2006,CD-ROM Proceedings (ISBN 0-9779007-1-1).

Reports and Papers in Press

Draut, A.E and Rubin, D.M., in press, The role of aeolian sediment in the preservation of archaeological sites in the Colorado River corridor, Grand Canyon, Arizona: U.S. Geological Survey Open-File Report.

Draut, A.E., and Rubin, D.M., in press, The role of aeolian sediment in the preservation of archaeological sites in the Colorado River corridor, Grand Canyon, Arizona, *in* Van Riper, C. and Sogge, M., eds., Integrating science and management on the Colorado Plateau: Tucson, Ariz., University of Arizona Press.

Gartner, J.W., and Ganju, N.K., in press., Correcting acoustic Doppler current profiler discharge measurement bias from moving bed conditions without global positioning during the 2004 Glen Canyon Dam controlled flood on the Colorado River: Limnology and Oceanography Methods.

Hazel, J.E., Jr., Kaplinski, M., Parnell, R., Kohl, K., and Topping, D.J., in press, Stage-discharge relations for the Colorado in Glen, Marble, and Grand Canyons, Arizona, 1990–2005: U.S. Geological Survey Open-File Report 2006-1243, 19 p.

Topping, D.J., Wright, S.A., Melis, T.S., and Rubin, D.M., in press, High-resolution measurements of suspended-sediment concentration and grain size in the Colorado River in Grand Canyon using a multi-frequency acoustic system, *in* International Symposium on River Sedimentation, 10th, Moscow, August 1–4, 2007.

Topping, D., Rubin, D., and Melis, T., in press, Coupled changes in sand grain size and sand transport driven by changes in the upstream supply of sand in the Colorado River: Relative importance of changes in bed-sand grain size and bed-sand area: Sedimentary Geology.

Wiele, S.M., P.R. Wilcock, and P.E. Grams, in press, Reach-averaged sediment routing model of a canyon river: Water Resources Research.

Reports and Papers in Preparation

Breedlove, M.J., Davis, P.A., Hazel, J.E., and Kaplinski, M.A., in prep., Using a geographically-integrated, remote-sensing methodology to evaluate the effects of Glen Canyon Dam operations on fine-grained sediment storage and sand bar restoration in the Eastern Grand Canyon.

Breedlove, M.J., and Schmidt, J.C., in prep., Spatial and temporal trends in the size and number of backwaters in Marble and Grand Canyons: An update of the Goeking and Schmidt study to 2005.

Davis, P.A., and Breedlove, M.J., in prep., Processing of multiple LiDAR datasets for monitoring changes in sediment resources within the Colorado River corridor in Arizona.

Hazel, J., Kaplinski, M., and Parnell, R., in prep., Effects of the November 2004 high experimental flow on the arroyo network at Palisades, Colorado River, Grand Canyon, Arizona: Grand Canyon Monitoring and Research Center draft final report, cooperative agreement 04WRAG0052, project no. 04052WS008, 33 p.

Grams, P.E., and Wilcock, P.R., in prep., Equilibrium transport of fine sediment over a coarse and immobile bed: submitted to Water Resources Research.

Kaplinski, M, Hazel, J., Parnell, R., and Kearsley, M., in prep., Campsite area monitoring in the Colorado River ecosystem from 1998 to 2005: the importance of flood flows to recreational resources: Grand Canyon Monitoring and Research Center draft final report, cooperative agreement 04WRAG0052, project no. 04052WS008, 24 p.

Ralston, B.E., Lauretta, M.V. and Kennedy, T.A., in prep., Comparisons of water quality and biological variable from Colorado River shoreline habitats under steady and fluctuating releases from Glen Canyon Dam.

Rubin and others, in prep., Relations between bed-sediment grain size, suspended sediment, topographic change in the Colorado River, 2000–4 (FIST reporting element).

Topping, D.J., Rubin, D.M., Melis, T.S., and Wright, S.A., in prep., Evaluation of conventional sampling, laser diffraction, and acoustics for measuring suspended-sediment concentration and grain size 1. Errors associated with conventional depth-integrated sampling: to be submitted to the Journal of Geophysical Research.

Topping, D.J., Rubin, D.M., Melis, T.S., and Wright, S.A., in prep., Evaluation of conventional sampling, laser diffraction, and acoustics for measuring suspended-sediment concentration and grain size 2. Development and evaluation of a laser-acoustic system: to be submitted to the Journal of Geophysical Research.

Yard, M., Ralston B.E., and Coggins, L.G., in prep., Response of drifting invertebrates and organic matter to disturbance from a high experimental flow along the Colorado River, Grand Canyon, AZ: to be submitted to River Research and Applications.

Abstracts Presented at Professional Meetings

Akahori, R., Schmeeckle, M.W., and Topping, D.J., 2004, Erosion characteristics of fine-grained, beach-building sediment along the Colorado River in Grand Canyon: EOS, Transactions, American Geophysical Union, v. 85, n. 47, F906.

Breedlove, M.J., Hazel, J.E., Kaplinski, M.A., Schmidt, J.C., Topping, D.J., Rubin, D.M., Fuller, A.E., Tusso, R., and Gonzales, F.M., 2005, Using an integrated, remote-sensing methodology to evaluate the effects of dam operations on fine-grained sediment storage and sand bar restoration in Marble Canyon: EOS, Transactions, American Geophysical Union, v. 86, n., 52, p. F614.

Hazel, J., Kaplinski, M., and Parnell, R., Monitoring arroyos with conventional survey techniques in Grand Canyon: 1996–2004: Grand Canyon Monitoring and Research Center Geomorphology Symposium (February 9, 2005).

Rubin, D.M., Topping, D.J., Wright, S.A., and Melis, T.S., 2006, Incorporating bed-sediment grain size in predictions of suspended-sediment concentration: three approaches tested using 20,000 bed-sediment grain-size measurements from the Colorado River in Grand Canyon: Fall AGU.

Schmidt, J.C., Topping, D.J., Grams, P.E., and Hazel, J.E., 2005, System-wide changes in the distribution of fine sediment in the Colorado River corridor of Grand Canyon National Park: Geological Society of America Abstracts with Programs, v. 37, n. 7, p. 331.

Schmidt, J.C., Topping, D.J., Rubin, D.M., Breedlove, M.J., Hazel, J.E., Kaplinski, M.A., Wright, S.A., Fuller, A.E., and Melis, T.S., 2005, High releases from Glen Canyon Dam cause short-term eddy-bar aggradation if timed to coincide with significant input of sediment from tributaries: EOS, Transactions, American Geophysical Union, v. 86, n., 52, p. F913.

Topping, D.J., Rubin, D.M., Schmidt, J.C., Hazel, J.E., Wright, S.A., Melis, T.S., and Kaplinski, M., 2005, Comparison of sediment-transport and bar-response results from the 1996 and 2004 controlled-flood experiments on the Colorado River in Grand Canyon: EOS, Transactions, American Geophysical Union, v. 86, n., 52, p. F906.

2005 Grand Canyon Monitoring and Research Center Science Symposium, Tempe, Ariz.

Coggins, L.G., Jr., Yard, M.D., and Gwinn, D., 2005, Mechanical removal of nonnative fishes in the Colorado River within Grand Canyon: Colorado River Ecosystem Science Symposium, Tempe, Ariz.

Draut, A.E., and Rubin, D.M., 2005, Investigating effects of the November 2004 high-flow release from Glen Canyon Dam on Aeolian sand-transport rates in the Colorado River corridor, Grand Canyon, AZ: Colorado River Ecosystem Science Symposium, Tempe, Ariz.

Hazel, J.E., Jr., Kaplinski, M., Parnell, R., Schmidt, J.C., Topping, D.J., 2005, A tale of two floods: comparing sandbar responses to the 1996 and 2004 high-volume experimental flow on the Colorado River in Grand Canyon: Colorado River Ecosystem Science Symposium, Tempe, Ariz.

Korman, J., and Campana, S., 2005, Effects of 2003–04 fluctuating flows from Glen Canyon Dam on the early life history stages of rainbow trout in the Colorado River: Part 2: Effects on young-of-year habitat use, growth, and survival: Colorado River Ecosystem Science Symposium, Tempe, Ariz.

Korman, J., Kaplinski, M., Hazel, J.E., Jr., and Melis, T.S., 2005, Effects of 2003–04 fluctuating flows from Glen Canyon Dam on the early life history stages of rainbow trout in the Colorado River: Part 1: Effects on the survival of eggs and alevins: Colorado River Ecosystem Science Symposium, Tempe, Ariz.

Palmer, S.C., Burbidge, C., and Cook, W., 2005, The electrical power economic impacts of liberalizing Glen Canyon Dam operational constraints: Colorado River Ecosystem Science Symposium, Tempe, Ariz.

Palmer, S.C., and Patno, H., 2005, Three years of experimentation at Glen Canyon Dam: the electrical power economic costs: Colorado River Ecosystem Science Symposium, Tempe, Ariz.

Schmeeckle, M., and Akahori, R., 2005, Flow, deposition, and stability or recirculation eddy bars in response to beach/habitat-building flows: Colorado River Ecosystem Science Symposium, Tempe, Ariz.

Schmidt, J.C., 2005, One hundred years of sand in Grand Canyon: Colorado River Ecosystem Science Symposium, Tempe, Ariz.

Topping, D.J., Rubin, D.M., Schmidt, J.C., Hazel, J.E., Jr., Melis, T.S., Wright, S.A., Kaplinski, M., 2005, Sediment transport and budget during the November 2004 controlled-flood experiment, with comparisons to the 1996 controlled-flood experiment: Colorado River Ecosystem Science Symposium, Tempe, Ariz

Walters, C., 2005, Surprise and opportunity in Grand Canyon adaptive management: Colorado River Ecosystem Science Symposium, Tempe, Ariz.

Yard, M.D., Coggins, L.G., Ralston, B.E., Kennedy, T.A., and Persons, W.R., 2005, Response of drifting invertebrates and organiz matter to disturbance from high experimental flows prescribed for the Colorado River, Grand Canyon, AZ: Colorado River Ecosystem Science Symposium, Tempe, Ariz.

Presentations at Recent TWG and AMWG Meetings

October 25, 2004 AMWG, Melis and others, 1) WY 2004 sediment experimental update Paria River inputs and 41,000 vs. 45,000 cfs sand bar simulations, 2) Summary Paria River sand inputs July 1–Oct. 24, 2004, Coggins and others 3) Update on mechanical removal treatments [PowerPoint presentations].

February 3, 2005 TWG, Melis and others, Experimental update on fine-sediment, 1) Review of Paria River sediment trigger and activity (2004–05), 2) Preliminary results of sand-bar area and volume changes as measured in the long-term monitoring sites measured repeatedly by the Northern Arizona University, Geology Department, 3) Preliminary results of the suspended-sediment mass balance for Marble Canyon for July 2004 through January 2005, as estimated by the USGS [PowerPoint presentation].

March 2, 2005 AMWG, Melis and others, 1) Update on preliminary experimental results associated with the November 2004 high-flow test at Glen Canyon Dam, Coggins and others 2) Results of hoopnet sampling to examine changes in juvenile humpback chub abundance and size before and after the 2004 experimental high flow, Korman and others 3) Review of conclusions from final report on rainbow trout studies in Lees Ferry reach [PowerPoint presentations].

August 30, 2005 AMWG, Melis and others, 1) WY 2004 experimental fine-sediment update between Lees Ferry and Diamond Creek, Sponholtz and others 2) Update on humpback chub translocation above Chute Falls [PowerPoint presentations].

March 8, 2006 AMWG, Wright and others, 1) Update on 2005/2006 tributary sand inputs and mainstem export–sand mass balance, 2) Update on specific experimental elements: 2a) Non-native fish suppression flows (5,000–20,000 cfs), 2b) Alternating low steady and low fluctuating flows (6,500–9,000 cfs versus steady 8,000 cfs), 2c) November 2004 High Experimental Flow, 3) summary of mass balance and experimental findings, Andersen and others, 4) Update on mechanical removal treatments, 5) Lees Ferry trout fishery summary, 6) Age structured mark recapture model of Grand Canyon HBC population using data through 2004, 7) Chute Falls translocation update [PowerPoint presentations].

May 2006 TWG, Topping and others, 1) Comparison of sediment-transport and bar-response results from the 1996 and 2004 controlled-flood experiments on the Colorado River in Grand Canyon, Draut and Rubin, 2) Final results of aeolian sediment-transport study: Implications for future weather monitoring in the Colorado River ecosystem [PowerPoint presentations].

August 1, 2006 TWG, Wright and others, 1) Sand transport during steady and low fluctuating flows in September/October 2005, Kennedy and others, 2) Comparison of food base data collected under steady versus low-fluctuating flows, Ralston and others, 3) Comparison of steady versus low-fluctuating flow aquatic sampling within backwaters, Anderson and others, 4) Update on near-shore temperature data collected under steady versus low-fluctuating flows [PowerPoint presentations].

November 9, 2006 TWG, Melis and others, 1) Status of sand supplies in the Colorado below Glen Canyon Dam, 2) Review of recommendations from Rubin and others memorandum of October 19, 2006, 3) perspectives on BHBF influence on biological and socio-cultural resources, Wohl and others, 4) Report of the physical resources monitoring peer review panel, with recommendation for ongoing high-flow sediment experimentation [PowerPoint presentations].

December 6, 2006 AMWG, Andersen and others, 1) Update on rainbow trout experimental studies in Lees Ferry reach, 2) Update on mechanical removal treatments, 3) Chute Falls translocation, Melis and others, GCMRC's experimental research update "sediment," 4) Update on 2004 sediment test findings, 5) 2006 status of sand supplies in the Colorado Below Glen Canyon Dam, 6) Beach/habitat building flow in FY2007, Overview of science recommendations, status of reports and update on BHBF science planning [PowerPoint presentations].