Temperature Control Device Workshop
January 22-24, 2001
Saguaro Lake Ranch
Mesa, Arizona

SUMMARY OF FINDINGS

PURPOSE:

The purpose of this workshop was to evaluate ongoing research and monitoring being conducted on the Colorado River Ecosystem (CRE), as defined by the Glen Canyon Dam Adaptive Management Program (GCDAMP), and to determine what modifications or additions should be made to the existing efforts to evaluate the effects of a temperature control device (TCD) on the dam, should the decision be made to construct and operate the device. Recommendations from the workshop would be used by the Grand Canyon Monitoring and Research Center, the Bureau of Reclamation, and other members of the GCDAMP in formulating and carrying out the scientific investigations charged with assessing the environmental effects of a temperature control device. Participants included individuals who are currently conducting, or have in the past conducted, research and monitoring efforts in the CRE, individuals who are conducting research and monitoring on other river systems in western United States, individuals who have served on peer review panels that have evaluated research and monitoring efforts in the CRE, and resource managers engaged in management of resources within the CRE.

REPRESENTED:

- Grand Canyon Monitoring and Research Center
- Fish and Wildlife Service
- Bureau of Reclamation
- Environmental Protection Agency
- National Park Service
- U.S. Geological Survey
- Arizona Game and Fish Department
- Utah Department of Natural Resources
- Utah State University
- Arizona State University
- Colorado State University
- Northern Arizona University
- Argonne National Laboratory
- SWCA, Inc.
- Ecometrics Research
- Reservoir Environmental Management
- Stevens Ecological Consulting

SUMMARIES OF PRESENTATIONS:

Speakers were asked to provide, where appropriate to their subject, answers to the following questions:

- Summary of variables being measured,
- Frequency and intensity of measurements,
- Methods of analysis,
- Ability to detect change in those variables,
- Recommendations for changes or additions to assess effects of a TCD.

OVERVIEWS

Dennis Kubly, Bureau of Reclamation, Salt Lake City, Utah and Barry Gold, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. The Glen Canyon Dam Adaptive Management Program: an effort to understand and manage the Colorado River Ecosystem in Glen and Grand canyons.

The geographic scope of the Colorado River Ecosystem as defined in the Glen Canyon Dam Adaptive Management Program (GCDAMP) is from the dam forebay to the western limit of Grand Canyon National Park, a distance of about 293 river miles.

The Colorado River's hydrology, sediment transport and water temperature were changed dramatically by closure of Glen Canyon Dam.

The Colorado River above the confluence of the Paria River is quite different from the downstream reach in water clarity and primary productivity, a result of sediment brought in by the tributary.

Number of fish species in the river has increased from about 10 prior to 1850 to about 23 at present. Number of native fish species have declined during this same period. Two of the five native fish presently are federally listed as endangered.

Formation of the GCDAMP was agreed to in the 1996 Record of Decision on the Glen Canyon Dam Operations Environmental Impact Statement. Major components include the Grand Canyon Monitoring and Research Center, Technical Work Group, and the Adaptive Management Work Group. The latter is a Federal Advisory Committee Act committee that makes recommendations to The Secretary of Interior.

The first large experiment conducted by the GCDAMP was a week-long, 45,000 cfs beach habitat-building flow that occurred in April 1996. Objectives were to rebuild high-elevation sandbars, restore backwater channels, retain fine silts and clays, restore the pre-dam disturbance regime, preserve and restore camping beaches, displace non-native fishes, scour vegetation from camping beaches, and protect cultural resources, all without significant adverse impacts to endangered species, cultural resources, the Lees Ferry trout fishery, or hydropower production.

The second large experiment conducted by the GCDAMP was an experimental flow for native fishes from March-September 2000. Flow components included: (1) short-term 8,000 cfs flows at the initiation of the study for aerial photography; (2) stable, spring flows of 14,000-19,000 cfs to measure hydraulic and water temperatures at the mouth of the Little Colorado River; (3) spring and autumn powerplant capacity spike flows; (4) an extended period of 8,000 cfs flows from during June, July, and August; and (5) a period of 8,000 cfs steady flows following the autumn spike flow to measure its effects and to conduct a second round of aerial photography. Year 2000 flows were conducted as a test of the development of a program of experimental flows for native fish. This flow program is one of several elements of the reasonable and prudent alternative issued by Fish and Wildlife Service to the preferred alternative in the Glen Canyon Dam Operations EIS.

Another element of the biological opinion is the evaluation of selective withdrawal from Glen Canyon Dam as a means of delivering warmer water to the Colorado River. The perennially cold water temperatures released by the dam prevent successful reproduction of the endangered humpback chub. Establishing a second spawning aggregation of humpback chub in the CRE is a third element of the biological opinion.

In January 1999 Bureau of Reclamation released a draft environmental assessment on a temperature control device for Glen Canyon Dam. The preferred alterative was a single inlet, fixed elevation design with an estimated cost of $15,000,000. Sufficient concern was evidenced in the review of the environmental assessment for unintended negative effects and the lack of a detailed science plan to measure those effects that the environmental assessment was withdrawn and not finalized.

A temperature control device workshop was convened in November 1999 to further develop issues surrounding the device and to work on development of the science plan. One outcome of the workshop was the discovery that native fish data had not been brought together and analyzed. Opinions of native fish biologists on the status of endangered humpback chub differed sufficiently to make obvious the need for the analysis.

During development of the Interim Surplus Criteria EIS in year 2000, Reclamation resource managers discovered that projections for utilization of the preferred alternative design for the temperature control device, previously estimated at 85 out of 100 years, were considerably overestimated and were closer to 45-50% of those years. This discovery has forced re-evaluation of the engineering designs for the temperature control device. Reclamation water quality modelers have undertaken analyses of release temperature deliveries with different engineering designs and have discovered that modification of a subset of the 8 inlets on Glen Canyon Dam may be sufficient to provide desired water temperatures.

Given these events and discoveries, it was decided to convene a second temperature control device workshop populated by scientists and resource managers who could provide knowledgeable input and recommendations on operation and assessment of effects to be integrated into the research and monitoring plan and the forthcoming environmental assessment.

<u>Barbara Ralston, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. Overview of long-term monitoring of biological resources along the Colorado River.</u>

Goals and Objectives: (1) Develop and implement monitoring plans that have a level of sensitivity to detect long-term trends of primary resources; (2) Balance sensitivity objectives with fiscal bounds—what is the level of acceptable risk? (3) Link resources via GIS database; (4) Distinguish between monitoring and research.

Monitoring Program Development: Step-wise process reflecting knowledge of resources and state of GIS capabilities in the system; (1) Inventory & cataloguing; (2) Life history development; (3) Ecological interactions; (4) Assessment & monitoring development

Current Status of Monitoring:

- Long-term monitoring in fine & coarse grained sediment (5 years);
- Terrestrial biological monitoring & inventory (3 years);
    - At present: (1) integrated monitoring of (a) vegetation composition and structure in new and old high water zone (4X/yr); (b) insect abundance on vegetation types (4X/yr); and (3) bird abundance and distribution (3X/year); (2) elevation change upslope and downstream; and (3) moving to random sites, but currently tied to historic sampling sites. Bird patch sites (104 total) 64/year surveyed 3X/year.
- Aquatic biological resource monitoring (in review); likely initiate 3 year program in 2002.
    - At present: (1) rainbow trout CPE, population estimates, recruitment; (2) mainstem fish distribution, recruitment, and population estimates in 2 high intensity native fish trips, two synoptic surveys at random sites, and one exotic fish trip in March; (3) aquatic foodbase density, biomass, and composition at fixed sites, not tied to fish sampling, but being considered; (3) water quality includes water temperature at 10 fixed downstream sites and conductivity at dam and Lees Ferry.

Long-term Overview:

- 3 years to determine minimum sampling and monitoring plan for terrestrial resources and 5 years for fully integrated habitat map;
- Aquatic biological resource monitoring (in review); likely initiate 3 year program in 2002;
- Will take 3-10 years to begin to see change/trends using present proposed methods.

MODELING

Amy Cutler, Bureau of Reclamation, Salt Lake City, Utah. Predicted temperatures from Glen Canyon Dam temperature control device alternatives using CE-QUAL-W2.

- Three design alternatives analyzed: (1) single inlet, fixed elevation at 3630' (assume use to 3670' with 40' submergence); (2) dual inlet, fixed elevation at 3630' (3670') and 3598' (3638'); (3) controlled overflow, variable elevation to 3580' (3620') with 2, 3, 4, or 8 inlets modified
- Analysis with CE QUAL W2 two-dimensional hydrodynamic and water quality model developed by Army Corps of Engineers; applicable to rivers, lakes, reservoirs, and estuaries
- Lake Powell elevation predicted to undergo greater future declines, on average, due to Upper Basin depletions and interim surplus criteria; previously predicted use for single inlet, fixed elevation design of 85 out of 100 years was incorrect; closer to 45-50% in next 50 years
- Alternative 1 expected cost $16.5 M could be used in ~50% of the next 50 years by current projections; Alternative 2 expected cost $28 M could be used in ~75% of next 50 years; Alternative 3 expected cost $42 million could be used in ~80% of next 50 years
- Preliminary results suggest modification of only a subset of the inlets with Alternative 3 might provide desired temperatures
- Effect on heat budget of Lake Powell appears minimal for all designs

David Harpman, Bureau of Reclamation, Denver, Colorado. The effect of a temperature control device on hydropower at Glen Canyon Dam.

- A temperature control device (TCD) may affect the production of hydropower at Glen Canyon Dam, relative to the “without” TCD case, by affecting the monthly water release volumes, by affecting the reservoir elevations and by affecting the relationship between generation, release and head (hydraulic efficiency effects).
- Relative to the “without” TCD case, monthly release volumes may differ during both the construction and operation of the TCD.
- Relative to the “without” TCD case, the reservoir elevation may be altered both during the construction and operation periods.

- Relative to the "without" TCD case, a temperature control structure will affect the hydraulic efficiency of the combined withdrawal and generation system.
- Summary of the Independent Effects of Changes in TCD Related Factors on Generation, Capacity and Economic Value.

	Monthly Release Volume		Reservoir Elevation		Hydraulic Efficiency	
	Increase	Decrease	Increase	Decrease	Increase	Decrease
Generation	positive	negative	positive	negative	positive	negative
Capacity	positive	negative	positive	negative	positive	negative
Economic Value	positive	negative	positive	negative	positive	negative

- The Glen Canyon Hourly Model (GCHM) is an hourly optimization model which simulates the operation of Glen Canyon Dam. The GCHM will be used to estimate the generation, capacity and economic value "with" and "without" the TCD. Analysis of newly identified TCD designs can be initiated as soon as the required "with" and "without" monthly release volumes, reservoir elevations, hydraulic efficiencies and operational parameters (e.g. number of penstocks on which the controls are installed and months when these are used) are developed.
- Two models have been constructed that could be of use to those considering the effects of a TCD. CONV01 is a utility program to convert water flow to water volume and vice versa. The GCPSE95 model allows for the rapid simulation of a wide variety of environmental constraints for policy analysis and experiential learning.

<u>Josh Korman, Ecometrics Research and Carl Walters, University of British Columbia, Vancouver, Canada. Grand Canyon conceptual model and stock assessment results: implications for experimental implementation of selective withdrawal from Glen Canyon Dam.</u>

Overview:

- Structure and assumptions of models that can predict native fish responses to warmer water temperatures
    - Data requirements are high to produce output useful for management decisions
- Description of stock synthesis approach used to derive time series of juvenile recruitment rates as a monitoring tool to evaluate TCD
- Experimental design challenges

Conclusions from Fish Component of Conceptual Modeling Exercise:

- Lack of data on fish predator-prey and competitive interactions and long term population trends limits use of Grand Canyon Conceptual Model for 'hypothesis screening'.
- We cannot predict with any certainty, even the direction of response to manipulations like selective withdrawal.
- Lack of trend data also means we have no way of experimentally evaluating proposed manipulations until adequate baseline data are available.

To evaluate experiments, most critical variable to measure is juvenile recruitment rate:

- What we have:
  - < Depletion sampling estimates of catchability (q) and population size (N)
  - < Mark-recapture estimates of population size (N) and adult survival (S_{adult})
  - < Catch per unit effort (CPE) and length-frequency data
  - < Very little data on abundance of age 1 fish – the critical variable
- Stock synthesis method combines the available information in modeling framework to back-calculate juvenile recruitment from catches of older fish.
- Compare recruitment trends to changes in physical habitat, i.e. did LSSF produce a large recruitment event.

The Success of the Program to Evaluate the TCD will Depend on:

- Magnitude of response, a function of magnitude of treatment and response to the treatment
- Natural variability, which can be reduced, in theory, by selecting indicators with low variability but the indicators with fastest response times are also highly variable
- Precision of monitoring methods, $'s, physical and institutional constraints
- Experimental design
- Duration of experimental periods
- Sequence of <u>all</u> Experiments

Challenges for the TCD Experiment:

- 3+ yr lag between treatment and measurement of response.
- 2+ yr lag on increased predation risk to due predator responses to warmer water
- At least 3 blocked treatments of 2+ yrs (or steady?). Duration = 10-15 yr experiment. Shorter treatments if you assume no effect of temperature on 1+ fish.
- Warming the water up is risky; can this risk be managed, and do we have a chance of observing the effect?
  - < Unproven monitoring program. What level of recruitment change can we detect?
  - < Confounding of TCD experiment with other treatments over that period highly likely.
  - < How risky is it if we do nothing for a while longer?

ONGOING FIELD RESEARCH AND MONITORING

Susan Hueftle, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona –Water quality assessment in Lake Powell and the Colorado River.

We have a rich 35 year dataset that has an abundance of physical (water temperature, dissolved oxygen, conductivity, pH, turbidity) and chemical (Ca, Mg, Na, Cl, SO_4, K) data with a few important holes (1980s).

Breadth of the monitoring expanded in the 90s to include a stronger biological and nutrient component.

The current program (subject to final PEP findings Feb '01) can detect seasonal and climatic changes in Lake Powell, restricted mostly to the mainstem and 2 or 3 side branches (Escalante, San Juan, Navajo).

Sampling intensity:

- Physical sampling is continuous (~20 minute intervals) for thermal data at the Colorado River inflow, forebay, in dam, and 20 points downstream.
- There is continuous conductivity, pH, dissolved oxygen and turbidity sampling in the tailwaters.
- Chemical, biological and non-thermal physical sampling is monthly in the forebay and tailwaters, and quarterly uplake. There is no consistent chemical or biological sampling conducted by Integrated Water Quality Program below Lees Ferry; sampling by other contractors addresses most food-base issues but little or no nutrients, nothing on a continuous basis.

Recognized shortcomings of the current monitoring program include :

- Meteorological data
- Diel plankton sampling
- Primary productivity at depth
- Forebay sampling for fishes
- Telemetered thermal sampling up and downstream
- Detailed inflow sampling for chemical and physical conditions

Sampling suggested to address these shortcomings:

- Hydro-acoustic sounding for both fish & plankton in the forebay (diel)
- Meteorological stations deployed on pump-out docks in lake
- Increased sampling (physical, chemical) of inflows if possible.

Joe Shannon, Northern Arizona University, Flagstaff, Arizona. Assessing aquatic food base patterns over the past decade in the Colorado River below Glen Canyon Dam.

- The summer of 2000 experimental flows altered the river temperature for an extended period of time for the first time in 38 years. The river doubled in temperature between Glen Canyon Dam and Lake Mead (10 - 20 °C). We recorded slight near shore warming and diurnal fluctuations (1 - 2 °C). This information demonstrates that dam operations can affect the temperature of the Colorado River through Grand Canyon.
- Our collections indicate the lowest food base estimates since the 1991 research flows. Biomass estimates decreased with distance from the dam even during periods of low tributary input. We suspect three possible causes; increase in river temperature, low nutrient concentrations and negative hydraulic response. Without rigorous field experiments we will not be able to prioritize these predictors.
- Given these temperature-related effects and not knowing the mechanisms for change, we suggest a request for proposals to conduct field experiments across trophic levels to better understand the potential effects of the TCD. The expected outcomes would include a better understanding of what changes may occur (test model outputs), what those mechanisms are and how to quantify them for an improved monitoring program. For example the cool stenothermic conditions during the past 38 years has selected for benthic taxa that can thrive in those conditions, that includes bacteria. A breakdown in the microbial loop resulting in a loss of nutrient mineralization and therefore nutrient concentrations could have been the mechanism for a loss of food base in western Grand Canyon. Only experimentation could test this hypothesis.
- Of the perennial 12 tributaries in Grand Canyon, Kanab Creek has water quality similar to the main stem and is a logical area for increased monitoring to track aquatic insect colonization. Tributaries are now monitored every other year for water quality and food base estimates.
- If the TCD is built it should not be considered an experiment but a part of normal dam operations. The experimental part is in it's operation so it best benefits humpback chub and other native fish. The TCD operation should be coupled with an aggressive non-native fish suppression program.

Wayne Gustaveson, Utah Department of Natural Resources, Page, Arizona.. The Lake Powell fishery.

- Measurement of the shad population should identify changes indicative of all elements of the Lake Powell sport fish. A large shad population is conducive to increased and more robust striped bass and smallmouth bass populations.
- Shad are currently measured with midwater trawl and tow nets. Trawl measures recruitment and tow nets measure production. Existing sampling has documented 3 year abundance cycles (pre-striped bass) and more recently a peak in 2 out of 10 years. Peak causes remain unknown.

- Entrainment potential may increase with a TCD and it would behoove us to perform hydroacoustics in forebay and related areas to identify magnitude and species which may be released downstream.
- Most striped bass spawning occurs in backs of canyons. Transport to dam would mean that current would have to be sufficient to transport eggs to dam in 48 hours (~10 miles) when hatching occurs. Now any eggs or larvae released are doomed to thermal shock from low release temperature. Warming would increase chance of striped bass egg/larvae downstream survival.
- Smallmouth have not passed from dam as yet for whatever reason? Warming would increase chance of downstream transport of smallmouth bass. My guess is low likelihood still but potential is enhanced with TCD.

Bill Persons, Arizona Game and Fish Department, Phoenix, Arizona. The Lee's Ferry rainbow trout fishery.

- Summary of variables measured to assess status and trends: (1) Electrofishing: date, time, RM station, effort (seconds), species, length, weight, PIT tag identification, sex, maturity, wild/hatchery origin (coded wire tags); (2) Creel: angler catch/hour, angler use (angler hours/month), satisfaction; (3) Snorkel Surveys: fish density/calibration efforts
- Frequency of sampling: (1) Electroshocking: 1984-1990, inconsistent; 1991-1996,15 sites, 3x / year, 2000 sec/site; 1997-2000, 9 sites, 3x / year, 2000 sec/site; 2001 - ?, 9 + 27 sites, 4x / year, 500 sec/site; (2) Creel:1965-1970, inconsistent; 1977-2000, monthly estimates (12d/month); 2001 - ?;1998-2000, exploratory; 2001 - ?36 sites 4x / year to evaluate, calibrate
- Methods of Analysis: (1) Descriptive statistics for status and trends--Catch per unit effort (CPUE), Kn (relative condition), proportional stock density, length frequency distribution; (2) Stock Synthesis Models--Age structured dynamic population model; calculate Walford/von Bertallanfy growth curves from mark/recapture.
- Ability to detect change: Power analysis and evaluation of electrofishing protocol--Preliminary results suggest that current protocol (1991-2000) was capable of detecting moderate variations in trout relative density and condition over both short (1-2 yr.) and long-term (5+ year) time scales; Results also indicate that detectable magnitudes of change vary considerably with fish size; Increases in number of sample sites and frequency of sampling should increase ability to detect short term change.

Lew Coggins, U.S. Fish and Wildlife Service, Flagstaff, Arizona. Native and non-native fish studies: Little Colorado River.

Current (Future?) LCR study objectives center around conducting stock assessment of the LCR humpback chub population.

- Recruitment variation.
- Juvenile survival rates.
- Population abundance and demographics.
- How GCD operations affects above.

LCR Monitoring Activities in 2000:

- Preliminary fall 2000 HBC abundance estimate of 1,590 HBC >134 mm in lower 14.2 KM of LCR in October (95% C.I. 992-2552).
- Fish Species Composition in the LCR was ~83% natives (44% HBC) and 17% nonnatives.

From 2001 Spring and Fall population estimates in the LCR:

- Over-winter survival/retention rate for juvenile fish in the LCR.
- Abundance estimates of spawning stock population.
- Post-monsoon survival/retention rate of juvenile fish in the LCR.
- First fix on year 2000 recruitment strength.
- Continued mark-recapture data collection for the Synthesis Model
- Fish community composition.

LCR HBC Synthesis Model under construction, motivated by Carl Walters.

- Age-structured stock assessment model "driven" by mark-recapture data.
- Synthesis of all mark-recapture (LCR and Mainstem) data to provide a time-series (~91 to present) of total abundance, demographics, recruitment, and survival estimates.
- Will provide the framework of a standardized annual stock assessment program.
    - Long-term sampling protocols and data collection requirements.
    - Will provide delayed assessments of dam operations effects on HBC.

Mainstem monitoring of LCR HBC.

- At least one trip (mid-summer) to monitor the mainstem haunts of LCR HBC (57 to 65.4 mile).
- Provide mark-recapture data for the "Synthesis Model".
- Assess movement between the mainstem and LCR and residence time in the LCR.
- Demographics of "mainstem" population.
    - Indication of increased juvenile survival in the mainstem.
- Assess change in juvenile mark rate between the LCR and mainstem.
    - Indication of increased juvenile survival in the mainstem.

Rich Valdez, SWCA, Inc., Logan, Utah. Native and non-native fish studies: mainstream.

Variables being Monitored, Methods of Analysis

- Distribution – longitudinal and time series
- Abundance – catch rate, mark-recapture, depletion
- Growth – mark-recapture, comparative stats
- Recruitment – stock-recruitment models
- Length-weight/K (Condition) factor – accurate weights
- Diet – stomach pump, sacrifice non-native fish
- Others (predation, age-growth, parasites, reproductive success, habitat)

Frequency and Intensity of Measurements:

- Five mainstem trips per year each 10-14 days long
- Trips in/for:
    - < March/April – non-native fish electrofishing; mark/recapture FMS, BHS
    - < May – Fish surveillance
    - < June/July – mark-recapture HBC
    - < Sept 15 – mark-recapture HBC; abundance/survival of YOY
    - < Dec/Jan – Fish surveillance

Ability to Detect Changes:

- Our ability to detect significant changes depends on five interacting factors:
    - < Sample Size
    - < Variability
    - < Level of Significance
    - < Power (probability of detecting a difference when one exists)
    - < Minimum Detectable Effect

Recommendations:

- Long-term Monitoring, Short-term Monitoring, and Research need to be integrated
- Clearly define objectives of Long-term Monitoring and Short-term Monitoring
    - < Maintain frequency and intensity of Long-term Monitoring
    - < Stay with original objectives of Long-term Monitoring
    - < Based on objectives, identify flexibility of sampling
    - < Refine/modify Long-term Monitoring program, as needed – but with CAUTION
- Determine if Long-term Monitoring measures parameters to evaluate TCD
    - < If not--implement Short-term Monitoring to tie cause-effect
    - < Time sampling to evaluate important elements

<u>Larry Stevens, Stevens Ecological Consulting, Flagstaff, Arizona.. Riparian communities and recreation.</u>

- Increased water temperature may result in increased lower riparian zone air temperature and decreased relative humidity, which may cause heat stress in plants and affect herbivores
- Potential mid to late summer impacts on vegetation composition:
  < Primary production
  < Invertebrate herbivore production
  < Avian and herpetofauna food availability
  < Decomposition rates could change
  < Link between aquatic invertebrate sampling and terrestrial invert sampling

Recreation

- Bacteriology–TCD may provide improved environment for disease organisms, especially *Shigella* during times of turbid water
- Swimming–Increased water temperature conducive to more swimming, greater body contact with water; tradeoff with reduced threat of hypothermia

DISCUSSION

Colorado River Resource Monitoring

Types and Definitions of Monitoring: (presented by Rich Valdez, taken from McDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. Publication EPA/910/9-91-001, U.S. Environmental Protection Agency and University of Washington.166 p.)

Monitoring terminology (from McDonald et al. 1991)
- <u>Trend Monitoring</u> – regular, well-spaced time intervals to determine long- term trend of a parameter
- <u>Baseline Monitoring</u> – characterize condition and establish data base for planning and future comparisons
- <u>Implementation Monitoring</u> – assess if activities are carried out as planned
- <u>Effectiveness Monitoring</u> – assess if activities have desired effect
- <u>Project Monitoring</u> – assess impact of a particular activity or project
- <u>Validation Monitoring</u> – to calibrate models
- <u>Compliance Monitoring</u> – determine if criteria are met

For the present discussion, the group defined two types of monitoring:

Core Monitoring – measure status and trends of high priority resources; schedule typically calendar driven; highly standardized, consistently applied methods and protocols, few changes once established

Effects Monitoring – measure conditions before and after management actions are taken; schedule typically event driven, set up to accommodate particular actions; more flexible methods and protocols

Monitoring and Management Actions Relative to the TCD

- Water temperature is modified as a consequence of modifying hydrology as evidenced in the experimental flows of year 2000: the two physical parameters should be considered together in planning and assessment of management actions
- Researchers need more lead time for design and implementation of research and monitoring assessments; water managers need to work more closely with scientists

Participants divided up into resource groups to develop recommendations for core monitoring and effects monitoring.

Physicochemical Group (A. Cutler, D. Harpman, S. Hueftle, C. Liston, D. Kubly, D. Robertson, J. Ruane)

Findings:

CORE MONITORING PHYSICOCHEMICAL VARIABLES			
Location	Uplink Continuous[1]	Continuous[2]	Monthly
Forebay	Water temperature	Conductivity, pH, dissolved oxygen, chlorophyll	Nutrients (P, N, TOC), hydroacoustic survey
Dam	Water temperature, discharge	Conductivity, pH, dissolved oxygen, chlorophyll	Nutrients (P, N, TOC), plankton, eggs

Downstream	Water temperature, flow	Conductivity, pH, dissolved oxygen, chlorophyll	Nutrients (P, N, TOC)

[1] Uplink continuous refers to satellite, radio, or telephone continuous sensing and relay of data
[2] Continuously recording sensors from which data periodically must be retrieved

Issues: Entrainment of undesirable fish, fish eggs, parasites (copepod intermediate host for parasites), whirling disease

Lower Trophic Levels (algae, invertebrates) Group (T. Angradi, C. Karas, J. Korman, J. Shannon, R. Vinson)

- Present sampling design is biased; needs statistical validation (strong emphasis)
- Change to randomized approach and clearly define the universe you are sampling; consider Environmental Protection Agency Office of Research and Development - Environmental Monitoring and Assessment Program (EMAP) approach; needs GIS foundation to define sampling universe and select sample sites
- Recommend two index periods—spring and fall
- Concentrate on three major habitats—cobble bars, backwaters, and tributaries; composite samples from each sample site
- Allocate 30-50 samples in each stratum
- Integrate physical habitat, water quality, lower trophic, and fish sampling

Fish Group: (K. Bestgen, R. Clarkson, L. Coggins, L. Crist, W. Gustaveson, J. Hayse, P. Marsh, B. Persons, M. Trammel, R. Valdez)

Core Fish Monitoring - LCR	
Trips	Purpose
May (1-2 weeks)	Suite of demographic parameters • > 100 mm TL pit tag • intensive mark-recapture • hoop net, trammel catch rates • stock synthesis models native fish emphasis
June (2-3 weeks)	
Oct (1-2 weeks)	
Nov (2-3 weeks)	

CORE FISH MONITORING - MAINSTREAM	
Trips	Purpose
March-April	Mark-recapture HBC, FM, BH aggregations in tributaries Spike flow camps Kanab Ck, Havasu Ck
Early April	Systemwide survey Lee's Ferry-Diamond Ck
May	Systemwide survey Lee's Ferry-Diamond Ck
Mid-May	Lees Ferry, native fish on spawning bars, trammel nets
June-July	Mark-recapture LCR area (HBC, FM, BH)
Sep	Non-native electrofishing, predator collections

Objectives:

1. Mark-recapture
   - LCR (800 in 2 trips) and mainstem (300-350 fish)
   - Suite of demographic parameters (abundance, age composition, survival, recruitment, growth, length-weight, condition factor (K_n)
2. Systemwide Survey
   - Lees Ferry - Diamond Creek–relative abundance, reproduction, recruitment
   - distribution of all species
   - stratified random design
3. Mark-recapture other aggregations
   - 30-Mile, Shinumo, Bright Angel, Kanab, Havasu, Middle Granite Gorge
4. Non-native electrofishing
   - stock synthesis model
   - predation

Other Considerations:

- Effects of pit tags >100 mm total length
- Food habits research–compare with 1991-93, 1996
- Parasites – Sample 50 humpback chub from LCR; 20 HBC mainstem
- Annual reporting, synthesis every 5 years
- Preserve otoliths dry for chemical composition analysis, compare LCR, mainstem, other tributaries

TCD Effects Monitoring

- Implement additional sampling if LTM does not adequately cover: (1) parasites (2) diet if there are significant food base changes
- Real time monitoring of fish movements–radiotelemetry?
- Contingencies in case of "thermal device failure," e.g. FGD
- Cause-effect differentiate stocks of HBC
- Chemical analyses of scale cores

<u>Riparian Group: (B. Ralston, L. Stevens)</u>

- Water Quality and Hydrogeology–Flows and current velocity, GIS/GPS study sites, water temperature systemwide and nearshore, air temperature and relative humidity systemwide (10 T_w sites)
- Instrument upstream and downstream of study sites with meteorological equipment to measure and model river and shoreline climate change
- After third year of TCD do dendrochronology of *Tamarix* and *Salix exigua*

- Measure secondary productivity of important insects, *Opsius* and *Idiocerus* or *Alconeura*
- Measure herpetofauna diet analysis as surrogate for riparian birds

Bacteriology

- Provide questionnaire to river runners for two years prior to and during TCD operation, consider involving Center for Disease Control, and educate river runners about safety concerns for swimming in the river

Large Group Discussion on Indicators: Much discussion centered on the lag necessary to use recruitment rate as an important indicator for humpback chub and other fish species. This led to an identification of other indicators that could be emphasized for different periods following management actions.

TEMPORAL INDICATORS OF CHANGE			
Resources	Early[1]	Mid	Late
Physicochemical	Water temperature System metabolism Allochthonous input (reservoir) C:N stable isotope ratios		
Lower Trophic	Phytobenthic & macroinvertebrate benthic biomass New colonists	Phytobenthic community composition	Macroinvertebrate community composition
Rainbow Trout	Reproductive success, Growth, New colonists	Sustained range expansion, Growth, Disease/ parasites, Population estimates	
Native Fish	Change in distribution, Reproductive success, Growth, Small-bodied exotic numbers, New colonists	Sustained range expansion, Growth, Disease/ parasites, Population estimates	Recruitment rate, Second HBC population, Down- and delisting of T&E

[1] Time periods not specified and may vary among resource categories

QUESTIONS AND ANSWERS FROM PARTICIPANTS

MONITORING OR RESEARCH

How is short-term monitoring different from research?

(Rich Valdez) *Short-term monitoring and research may be synonymous in that each is driven by a particular question over a short time period. There is in my mind a distinction: monitoring will require routine and repeated sampling of a given parameter in order to assess the status and trend of that parameter over time. Short-term monitoring generally complements a more expansive long-term monitoring program where the routine is insufficiently sensitive to detect a given change. For example, for a temperature control device, we may want to know the response by nonnative fishes with high reproductive rates and short generation times; i.e., do they reproduce successfully, survive, and recruit? Periodic sampling will provide us with this information. Research is driven by testing of hypotheses and is generally best conducted under controlled conditions–which we do not have in a system the size of the Colorado River. If we implement a temperature control device, what effect will the temperature increase have on given fish species. Effects of temperature on humpback chub and flannelmouth sucker have been conducted in laboratory studies. Additional research on this question may be needed for other species.*

(***Dale Robertson***) *Research is all in the eyes of the beholder. Research ranges from short-term molecular processes to long-term examination of global climate change. By the definition used in this workshop, all short-term studies are research and addresses some type of process that can be addressed quickly so as not to break the bank. Hopefully part of the short-term studies will be part of the long-term monitoring, otherwise none of the short-term studies were really part of the monitoring program.*

What or how are questions asked that distinguish monitoring from research? ***(Rich Valdez)*** *There seem to be considerable misunderstanding about distinction between research and monitoring. I would refer people to EPA Guidelines for Region 10 by MacDonald et al. (1991). Simply stated, to monitor a resource is to identify a given parameter and measure that parameter at regular intervals using the same sampling routine (e.g., same gear). We have never done this for native fishes in Grand Canyon, except for short periods of time. Since 1958, 12 major investigative groups have sampled fishes in Grand Canyon. No two groups have used the same gear types or sampled with the same routine. These investigations have been driven by different objectives, including taxonomic studies, life history studies, and dam operations studies, including some research elements. Research is driven by hypothesis testing; monitoring is driven by the definition of the status and trend of a given resource over time. Most of the investigations in Grand Canyon have surveyed* *the river to reconnaissance the distribution and occurrence of fish, and to attempt to relate fish population response to dam operations. We are only recently starting into a program of monitoring native fishes through Grand Canyon with fixed numbers of trips each year, a fixed array of gear types, and a defined sampling routine. This program will take some years to refine (as we did in the upper basin), but the information is valuable to assess the trajectory of a given resource.*

(***Dale Robertson***) *Again, why do we have to distinguish the two?*

Does/should monitoring differ with a TCD; is this an operational effect?

(***Rich Valdez***) *A long-term monitoring program needs to be developed and implemented for native fishes in Grand Canyon. This program would be based on a regular sampling routine designed to document the status and trend of the humpback chub, flannelmouth sucker, and bluehead sucker. This program would be ongoing when the TCD is implemented. If the sampling routine for the long-term monitoring program is determined to not be sufficiently sensitive to assess certain aspects of a TCD, additional sampling should be done (i.e., short-term monitoring) to supplement the long-term monitoring program. The long-term monitoring program should not be altered or modified for a single event such as a TCD; the long-term monitoring program should go on regardless of management actions, since the focus should continue to be the status and trend of the resource.*

(***Dale Robertson***) *Not if it is monitoring. If they differ, you will not be able to tell the effects of the TCD.*

DECISION PROCESS

How much variability in temperature needed annually?

(***Dale Robertson***) *More than background variation. Temperatures higher that what are experienced during present extreme conditions.*

Current and historical sampling is spatially and temporally biased. What are potential consequences of this approach?

(***Dale Robertson***) *None if it is incorporated into the analysis. Stratified random.*

What will the effects of beach habitat-building flows be on the ability to release warm water?

(***Dennis Kubly***) *Under current operational scenarios, beach habitat-building flows will only occur in years of high reservoir content and during spring months prior to that time of year when we would (and could) be releasing warm water. Thus, there would be little to no effect unless the time of year for beach habitat-building flows is changed.*

Will dam operations change between the management action and recruitment?
(***Dennis Kubly***) *I assume by "dam operations" the questioner means release schedules and volumes and that "recruitment" refers to humpback chub. Yes, it is unlikely that the same release schedules and volumes will occur over the period of time, say three years, between a management action and recruitment of humpback chub that were reproduced in the year of that management action. Release schedules and volumes will be determined by reservoir volume, inflows, and delivery commitments, all of which can change from year to year.*

Have "decision tree" analyses been considered to address TCD alternatives?
(***Dennis Kubly***) *Considered yes, implemented no. Most effort has been directed at: (1) determining our ability to release sufficiently warm water from Glen Canyon Dam during the appropriate time of year to benefit humpback chub; (2) assessing the status of the target species (primarily humpback chub) and other taxa with which the target species interacts (food resources, competitors, predators, parasites); (3) identifying potential negative effects of a TCD; (4) developing a science plan to assess those effects if we construct and operate and; completing an environmental assessment to satisfy provisions of the National Environmental Policy Act.*

What is the acceptable time to detect a change/response?
(***Dale Robertson***) *Depends on the response variable. Here we seem to be talking about the HBC. If the HBC pulls off a year class once ever 4-5 years. I think we need to run the various scenarios for about 10 years before we can say much.*

DESIGN CONSIDERATIONS

TCD

Is the TCD looked at as if it is a test? If so, and if the effects of the TCD were positive, why would we want to stop use of the TCD.
(***Dale Robertson***) *We wouldn't. We should have the background data before the TCD is started. Therefore, after 10?? years, we will have the after effects. So, the test should be complete, and we can decide which condition is better. If it is positive, why not continue it? Unless there are other scenarios to test.*

Is BOR considering surface water pumps which could provide a greater range of operating flexibility in providing target temperatures over a wider range of water surface elevations? The pumps also could be used to oxygenate low DO waters in some years.
(***Dennis Kubly***) *Yes, surface water pumps are being considered as a means of moving warm surface waters down to penstock level. It appears that the depth to penstocks is too great*

at high reservoir elevations, and thus the surface water pumps would not suffice as a total solution. It may well be, however, that surface water pumps could be added at some time in the future, particularly if modification of a subset of the intakes is undertaken as a preferred alternative. The primary purpose of surface water pumps in that scenario would be to drive warm water to the penstocks during years when the reservoir was too low to use the intakes modified for the TCD.

With only partial structure modification, what about thermal stratification downstream?
(***Dale Robertson***) *Don't understand? Given the flow in the river downstream, I can't see how much stratification would develop downstream.*
(***Amy Cutler***) *See response to questions posed to presenters*.

What are the percent of years in which all intakes would be operational?
(***Dennis Kubly***) *TCD intakes could be "operational" in all years during which reservoir elevations were high enough to release water through the intakes, i.e. it depends on which engineering design is selected. The only other limitation on intake use would be during times of facility repair, most of which is planned and scheduled. We believe only a very small percentage of unplanned outages would interfere with their use. Whether it would be desirable to operate all intakes in every year is a question whose answer will be defined by the objectives of the TCD operation and addressed through the research and monitoring program.*

LP/tailwater fishery tie-in – is there now an export of fish from Lake Powell (significant, eggs, adults). Would potential TCD operations alter existing scenarios? Does particulate organic matter export from Lake Powell show up in tailwater diet (to any significant level)?
(***Bill Persons***)

- *There is no evidence of export from studies in early 1990's (coded wire tagging thousands of hatchery fish). Significant export seems unlikely in light of behavior patterns of RBT, but under high densities of trout export is suspected by some. We have no evidence of export of adults, again from studies done during Phase II of GCES. Export of adhesive RBT eggs is unlikely. The most likely affected life stage is early swim up fry and small juveniles, possibly under higher flows. We looked for but saw no real evidence of export during 1996 BHBF, although there was a slight decrease in catch rates (electrofishing) of small fish within the Lees Ferry reach. Some of this could have been due to stranding or direct mortality.*
- *We have no evidence of POM export from LP in diets in the tailwater, may be more important for larval native fishes downstream where LP POM seems to be a very important part of zooplankton community. Larval cyprinids and catastomids consume zooplankton (we're still trying to get a paper out on this...).*

Has BOR considered the withdrawal zone for individual units (suspect that units 1 and 8 have warmer temperatures) especially if you modify <4 units?
(***Dennis Kubly***) *The major consideration for which units has been in the engineering, i.e. are lateral units easier to modify, and in environmental consequences, i.e. is the potential for entrainment greater in later units.*

With reference to the TCD: Would the "top" be replaced on the TCD? Has a model been used to estimate the best temperature regimes for the releases?

(***Dennis Kubly***) *(1) Yes, with designs being considered new trashracks with removable tops would be installed. (2) The "best temperature regimes for the releases" have not been determined. Engineers can provide us with very good estimates of what water temperatures can be obtained with different designs under different reservoir elevations. We would have to define what temperature(s) is "best" through a research and monitoring that determines whether we were meeting our target objectives for operation of the TCD.*

MONITORING

TCD fish monitoring: If response time is not truly measured for 3+ years, what periodicity of operation could possibly make sense?

(Rich Valdez) *The supposition that response time for humpback chub is not measured for 3+ years is not entirely true. Annual monitoring of year-class strength (i.e., young hatched every year), as well as annual survival of these fish, will tell us what conditions produced a successful year class and if the fish are surviving. If we rely on models alone to tell us if recruitment is occurring, these models will not tell us why fish are surviving or not surviving past their first year of life. After all, the most important aspect of monitoring these fishes is to determine how we can increase survival, recruitment, and ultimately population size. We have learned this from monitoring Colorado pikeminnow in the upper basin, where we have identified one to three strong year classes following a high-magnitude runoff. These strong year classes have consistently translated into a pulsed recruitment into the adult portion of the population. The objective now is to manage the flow regime to reduce the recurrence interval of high-magnitude runoff flows and increase the frequency of occurrence of strong year classes.*

(***Dale Robertson***) *Again, I would suggest close to a 10 year test to incorporate climatic variability and some year class development.*

Short-term monitoring should focus on measuring changes in habitat and water quality. Shouldn't these changes shed more light on long-term changes in the fish?

(Rich Valdez) *Monitoring water quality is a valuable asset to any program and should be continued in Grand Canyon and Lake Powell. However, monitoring habitat may not be a reasonable way to assess the eventual success of a given fish population. Monitoring habitat is a controversial issue in the upper basin. Most biologist agree that there is not a direct relationship between habitat and fish density, except in extreme cases; other compensatory and density-dependent factors complicate this relationship. Hence, to say that the fish population is doing well or poorly because of certain habitat conditions oversimplifies the issue. Releases from Glen Canyon Dam have been fixed through a*

NEPA and a ROD. Unless we plan on changing the MLFF regime, monitoring habitat is a futile exercise. Our money and time is better spent monitoring the target resource(s).

(***Dale Robertson***) *I wouldn't expect these to change overnight, so I don't think these should be considered short-term monitoring. Some things like water quality will continue to have effects and therefore should also be continued.*

What benefit (results affecting decisions) have been documented by short-term monitoring? Of fish?

(Rich Valdez) *The only times we have implemented "short-term monitoring" is during the 1996 Experimental Flood and during the 2000 Low Steady Summer Flow. Results of the 1996 flood showed that releases of high magnitude can disadvantage small-bodies nonnatives for short time periods, and effectively reduce numbers of competitors and predators of young native fishes. This is a valuable management tool for potentially increasing survival of young native fishes. Results of the 2000 LSSF showed us that low steady releases of 8,000 cfs will warm the river considerably and provide suitable temperatures for mainstem spawning by native fishes downstream of the LCR. Short-term monitoring during the LSSF also showed us that a late summer (i.e., September) spike release of power plant capacity (i.e., 30,000 cfs) could displace large numbers of young native suckers. We may want to delay this spike in future tests to allow the fish to grow larger, or not have a fall spike.*

(***Bill Persons***) *Trout population responses have been documented by LONG term monitoring. Decisions (ROD) were based more on research findings from Phase I & II GCES.*

What can be accomplished with long term monitoring once or twice per year (e.g., fall sampling like the FWS on LCR)?

(Rich Valdez) *At this time, a long-term monitoring program for native fish in Grand Canyon will need include more than two samples per year. We believe four or five annual sample periods are needed. However, over time, we may identify the time of year to best assess a given parameter, and reduce the number of sampling trips. I suspect this will be the case. In the upper basin, it took us nearly 5 years to determine that the best time to monitor age-0 Colorado pikeminnow was in late September and early October.*

Is sampling fish accurate enough to analyze at any other than a seasonal basis?

(***Dennis Kubly***) *To my knowledge, analyses of existing data directed at answering questions such as this have not been conducted. These questions need to be addressed for fish and other resources as was indicated in the workshop.*

One of our toughest questions as managers is "what level of change do we need to be able to detect." How do we address these metrics? What is the acceptable level of risk?

(Rich Valdez) *The precision and accuracy of monitoring data can be determined through power analyses of existing data. We have learned in the upper basin that acceptable levels of* *precision often require more sampling and therefore cost more money. For example, a 3-pass multiple mark-recapture estimate will yield 35-40% upper 95% CI around the mean. To improve the precision of that estimate to 20-25% of the mean, will require a 4th pass, and therefore additional trips and logistical costs. Also, this level of resolution also requires additional handling of fish, which must also be a consideration. The bottom line is that with native fishes, we are not able to get very precise estimates of abundance to detect small changes in numbers. That does not mean that we should not monitor because these populations function on the basis of catastrophic changes in young survival and recruitment. Had we been monitoring the adult portion of the razorback sucker population in the upper basin through the 1970s and 1980s, we would have believed that the population was stable, when in fact, there was no young survival and recruitment, and the population grew senile and crashed. We need to understand that we cannot monitor for small changes in populations, but we must monitor for continued losses of age classes and lack of recruitment over long time periods.*

(Dennis Kubly) *Questions such as these are just now coming up in GCD AMP discussions. In particular, I hear the water and power managers express disbelief that after all the time and money spent on monitoring, we still do not know what level of change can be detected in priority resources or whether we can assign cause and effect (from dam operations) to those changes. Scientists in turn point out that there has not been a consistent monitoring program in the CRE. From my perspective, it is the managers and decision-makers who have to make the cut on "acceptable level of risk." They should do so intelligently, however, and this can not be done without an understanding of the consequences of being wrong. So, scientists need to educate managers about the consequences of making bad decisions on resources of interest. Scientists also should be in a position to identify the costs of improving the quality and quantity of data that will serve to lower the risk of making bad decisions if used appropriately.*

Current sampling programs are not well integrated. Can indicators (WQ, macrobenthos, phytobenthos, physical habitat, fish, stable isotopes, microbes, etc.) be collected at the same times and places? Makes discerning associations among indicators possible.

(Rich Valdez) *A common mistake that is made with monitoring is the tendency to monitor everything. Monitoring must identify a purpose and objective and target a given resource. Cause-effect relationships should be identified from models or research components. We cannot expect to monitor all resources simultaneously. Sampling schemes will not allow this. The most effective monitoring programs are those that have continued over time with a simple design. The important species often get lost in complex, multiple-resource monitoring programs, which dilute effort and funding.*

(***Bill Persons***) *Some of these samples can and SHOULD be collected at the same times and places. Coordination has been limited in the past.*

(***Joe Shannon***) *It does sound appealing to collect all aquatic community constituents at the exact time and place, however in the river monitoring/river health literature this is not a high priority. These types of sampling regime questions are really related to the monitoring objectives. In GC collecting within the same month is the most realistic.*

Large River monitoring and assessment moving in direction of EMAP approach (EPA-ORD). Should Colorado River (Grand Canyon) monitoring include some aspects of this approach?

(***Bill Persons***) *Yes, randomization at some scale is important.*

(***Joe Shannon***) *I would hope that GCMRC/BOR would elevate the long-term monitoring program to the same level that is occurring in North America and around the world. EPA is the responsible agency for water quality in the US and they are have a sound basis for random site selection. The fundamental problem is the attachment to previous data sets and the science leadership having the courage start with a new program and create a new baseline data set.*

(***Dennis Kubly***) *This subject generated more interest and discussion than any other at the workshop. Questions about sampling design typically are addressed at the outset of a program, and before the field work begins. It appears that more time and attention will have to be given to answering these questions before any long-term program is put in place.*

MODELING

For the conceptual model, there are likely sources in the literature for coefficients in the model. Have these been used in the sensitivity analyses?

(***Josh Korman***) *We parameterized the model given data from Grand Canyon, or data from the literature (FishBase), or Carl Walter's extensive experience. A sensitivity analysis will reveal that there are many possible outcomes, something we already know, so there is no point in doing it. The real uncertain parameters cannot be measured or found in the literature (change in P/F, effect of changing P/F under different habitat conditions) – the net result of the change could be measured via a large-scale field experiment.*

In the conceptual model, can the simplistic models become over parameterized given the available data?

(***Josh Korman***) *Simplistic model over parameterized – seems a bit contradictory/confused. I wouldn't call the model we developed simplistic in any sense. But yes, the data is insufficient to apply the model for predictive purposes. The alternative is to create a simplistic/ moronic model (e.g. warmer temperature = more native fish) that can easily be applied, but will probably be dead wrong.*

Have other models been used to estimate temperature (other than BETTER) in the Glen Canyon Dam discharge?

(***Amy Cutler***) *Yes, in fact we are currently using a 2-D hydrodynamic water quality model call CE-QUAL W2 to model discharge temperature from the Glen Canyon Dam.*

Have models been used to simulate temperature hourly at various locations downstream?
(***Dennis Kubly***) *No, this has not been done. The result of this simulation would differ between the thalweg and nearshore habitats, particularly backwaters, where water is entrained, velocities diminish, and solar energy can be accumulated in the water.*

Is the TCD being designed in a way so that temperature can be adjusted if "predicted" temperature is not as expected?
(***Dennis Kubly***) *Yes, the existing designs allow mixing of warm water drawn through high elevation inlets and cold water drawn through the penstocks to achieve the desired temperature.*

Have BOR/modelers calculated the potential of very different run-off patterns in the future, i.e. global warming models predict years of zero spring snowpack within next two decades?
(Amy Cutler) No, we have not looked into these types of extreme patterns yet.
(***Dennis Kubly***) *Are there global warming models that predict years of zero spring snowpack within the next two decades?*

Does the TCD CEQUAL-W2 modeling indicate that the simulation of Lake Powell may be altered by TCD operations?
(***Amy Cutler***) *Yes, the model does show a small change in the thickness of the thermocline assuming a set of hydrological and operational condition is used.*

With reference to the year 2000 flow experiment, was hydropower peaking considered in setting up the steady flow operating regime, i.e. was modeling used to determine how much peaking could be used while establishing "steady flows" downstream?
(***Bill Persons***) *No, but think this is a good question, and think it is possible to allow some peaking while maintaining stable flows at the mouth of the LCR.*
(***Dennis Kubly***) *Perhaps, but there were "steady flow" hypotheses directed at resources in the Lees Ferry reach below the dam as well as downstream.*

FISH

Are there questions (research) we could ask (answer) now about the non-native fish that might be valuable (or critical) to a go – no go TCD decision?
(Rich Valdez) *Yes–a comprehensive synopsis of the life history of each native and nonnative fish species in Grand Canyon should be performed as the foundation for a risk assessment, whereby we assess the risk of a TCD as a benefit or detriment to native fishes, especially humpback chub. There is a considerable amount of literature on nonnative fishes from other regions of the country, including temperature tolerance, flow tolerance, etc.*

Thermal shock occurs frequently below many hydropower projects without "significant" biological impacts. If thermal shock is "significant" below GCD, why is it?

(Rich Valdez) *The effects of temperature below Glen Canyon Dam were manifest by the mid to late 1970s, when Lake Powell filled and the release temperatures became 8-10°C. Increasing the temperature to 15°C is not likely to cause "thermal shock" to fish below the dam. This temperature is within the preferred temperature range of trout and downstream warming will provide more suitable conditions for native fishes.*

(Rob Clarkson) *Please refer the interested reader to: Clarkson, R.W. and M.R. Childs. 2000. Temperature effects of hypolimnial-release dams on early life stages of Colorado River Basin big-river fishes. Copeia 2000(2):402-412. This paper looks at temperature effects of dams on big-river fishes to look for answers to the following questions: Thermal shock occurs frequently below many hydropower projects without "significant" biological impacts. If thermal shock is "significant" below GCD, why is it? What is the risk if we do not warm the water?*

How practical is direct control of non-native piscivores/competitors? Can an experiment be done?

(Rich Valdez) *Yes–we have proposed to conduct a pilot study by seining backwaters throughout Grand Canyon and removing all nonnatives captured. This would be valuable to know if we can direct efforts and effectively control nonnatives in nursery areas of native fishes. Furthermore, channel catfish and carp can be effectively controlled in the lower LCR. Previous attempts have not sampled the area at the right time.*

(Bill Persons) *We've done minor, very small-scale investigations of predator removal, primarily with channel catfish in the LCR. It has not been practical to date. See the Valdez et al. paper.*

How does biology of humpback chub influence lag time to detect a TCD effect? Do they spawn every year? Does it depend on temperature or food supply?

(Rich Valdez) *The key response parameter for humpback chub will be reproductive success. This can be determined immediately as indicated by larval and juvenile humpback chub in the mainstem. This year class should be monitoring for at least 3 years to determine if recruitment to the adult portion of the population has occurred. The proposed stock recruitment model only looks at the adult portion of the population. I believe we need to identify year class strength and determine the factors for successful survival. We believe at this time that most, but not all of adult humpback chub spawn every year. Spawning by humpback chub appears to be phased; readiness is driven by photoperiod and food supply, final gonadal maturation by water temperature, and spawning by flow conditions and water temperature.*

(Lew Coggins) *Unknown*.

Is juvenile recruitment rate the right response variable?

(Rich Valdez) *Juvenile recruitment rate is one of the right response variables. The right response variables are (1) reproductive success, (2) year class survival, (3) juvenile survival, (4) juvenile recruitment, and (5) adult abundance.*

(Lew Coggins) *I think that it is since it will ultimately be the measure of success of a TCD or any other manipulation.*

(***Dennis Kubly***) *The question reflects the large amount of emphasis that seems to be placed on recruitment rate and stock assessment in the ongoing research and monitoring program. As indicated, humpback chub recruitment rate can not be measured until 3-4 years of life, and 2-3 years after fish can first be marked. Hydrology of both the LCR and mainstem may vary dramatically over the course of time from birth, to marking, and then recruitment into the adult population. If one seeks to ascertain what the effect of temperature is on reproductive and recruitment success, it will be very difficult to separate out the confounding effects of differing hydrology that occurs during the same time period. I do not think this problem has been adequately addressed in existing research and monitoring designs.*

If there is mainstem spawn, how do we separate mainstem hatch from LCR hatch?

(Rich Valdez) *The only direct evidence of mainstem spawning is in a warm spring at RM 30 (Valdez and Masslich 1999). Occurrence of small, post-larvae considerable distances downstream of the LCR suggest mainstem spawning, but none has been verified. Studies by Valdez and Ryel (1995) reported from scale back-calculations that there was little or no survival of humpback chub descending the LCR at less than 52 mm total length. With reproduction in the LCR peaking in April and May (before the TCD), appearance of larvae and post-larvae in the mainstem during June and July (time of spawning readiness for mainstem fish) would strongly suggest mainstem spawning.*

Valdez, R.A. and W.J. Masslich. 1999. Evidence of reproduction by humpback chub in a warm spring of the Colorado River in Grand Canyon, Arizona. The Southwestern Naturalist 44(3):384-387.

(Lew Coggins) *For the LCR aggregation, we will attempt to make this separation by observing different mark-recapture rates between Mainstem sampling and LCR sampling. Another option being discussed is further consideration of otolith chemistry.*

Is a 2-3 year lag time okay for assessing responses in the kind of adaptive management program?

(Rich Valdez) *No–we need to be monitoring year class strength of newly hatched humpback chub and determine if survival is occurring through the first 3 years of life to age of recruitment.*

(Lew Coggins) *Whether it is OK or not, it is likely the best we can do.*

If we spell out a design and treatments can they be realized?

(Rich Valdez) *Yes–we have developed a preliminary design for monitoring. The monitoring should go forward regardless of what happens with the TCD. Implementing treatments will require careful and focused monitoring to ensure that important parameters are measured.*

How long should treatments (warm water) be?

(Rich Valdez) *The TCD should be viewed initially as a test with warm water released during the entire period of availability (15°C) in at least the first year. Results should be used to guide subsequent releases.*

(***Joe Shannon***) *Once the TCD is turned on it should become part of "normal" operations. Vinson et al. have the the best data set from Flaming Gorge and they are still documenting changes in the aquatic community after a decade. Managers need to understand biological response time and the ability of scientists to detect the change. The Summer 2000 flows are a good example, flows directed at the chub, but the LCR spawn was weak. So was it a good year to evaluate summer steady 8K cfs? Yes, from a science view, no, in terms of chub population enhancement.*

If we can't measure it, should we do it?

(Rich Valdez) *Yes, we should do it, even if we can't measure all of it–but we can measure much of it. Many people seem to think that an evaluation that does not follow strict and absolute quantitative and statistical guidelines is of no value. I disagree. An important component of scientific investigation is observation–in fact science was born from observation. To many scientists today, the works of Copernicus, Galileo, or Newton would not be considered science because they did not use intricate statistical analyses nor did they collect data with the aid of the technological instrumentation of today. An important part of science is the observation of trained minds. Yes, we must strive to measure and quantify effects, where possible, but these measurements are tools for interpretation; the most valuable asset that is too often discounted are the observations of trained and experienced professionals in the process of data collection. What we learn as investigators during data collection serves as a cohesive for subsequent data analyses and interpretation. On-going long-term involvement by investigators that involve themselves in field data collection is a valuable asset to any resource project.*

What is the risk if we do not warm the water?

(Rich Valdez) *For the fish, there is little direct risk. However, if there is an effect to macroinvertebrate communities from warming/cooling from operating or not operating the TCD, there could be an effect to food supply.*

How has humpback chub changed since implementing the operating changes at Glen Canyon Dam?

(Rich Valdez) *We do not know the current status and trend of the humpback chub population in Grand Canyon. Simultaneous population estimates in the LCR and mainstem during 1991-95 show that the population supports about 4,000 adults in the LCR and about 1,000 in the mainstem. During this period of monitoring, the population appeared to be stable with recruitment equal to mortality of adults. After 1995, program emphasis was changed away from population estimators and we do not have good empirical data on the status and trend of the population.*

Can the predators be "managed?" (i.e. kill off a bunch)

(Rich Valdez) *Yes–we cannot remove nonnative predators from the system, but we should be able to control their numbers, especially at key times, such as during spawning and larval emergence of native fishes. A Nonnative Fish Control Strategy for Grand Canyon has been described by Valdez et al. (2001).*

Valdez, R.A., B. Persons, and T.L. Hoffnagle. 2001. A non-native fish control strategy for Grand Canyon, Arizona. In: C.L. Springer and S. Leon (eds). Proceedings of two symposia. Restoring native fish to the lower Colorado River: Interactions of native and non-native fishes. July 13-14, 1999, Las Vegas, Nevada. Restoring natural function within a modified riverine environment: The lower Colorado River. July 8-9, 1998. U.S. Fish and Wildlife Service, Southwest Region, Albuquerque, New Mexico.

(Bill Persons) *Sounds like a research question to me…*

(***Dennis Kubly***) *A nonnative control strategy is being employed in the Upper Colorado River Basin as a means of negatively impacting fish that are competitors with or predators on native fish. The foundation of this strategy is contained in the following document: Tyus, H.M, and J.F. Saunders, III. 1996. Nonnative fishes in the Upper Colorado River Basin and a strategy plan for their control. U.S. Fish and Wildlife Service, Denver, CO. 85 pp. We have been remiss for quite some time in not seriously considering a similar effort in the Grand Canyon region.*

How do you measure if you have "advantaged" warm water or cold water fishes? (What do you measure?)

(Rich Valdez) *We can measure (1) evidence of reproductive success (i.e., presence of larvae, fry), (2) survival as indicated by relative abundance estimates (e.g., numbers of fish/100 m^2 seined), (3) range expansion or increased distribution or abundance where previously absent, (4) increased abundance of adults indicating recruitment, and (5) invasion and persistence of new species.*

(Bill Persons) *Population responses over several years – recruitment seems to be the best way to get a fairly good assessment. If we have to wait to measure a change in population size, it could be a long time.*

What is the lag time till you know? (How many years to recruitment?)

(Rich Valdez) *Humpback chub recruit in 3-4 years; i.e., males typically mature at about 185 mm total length and 3 years of age, and females typically mature at 200 mm total length and 4 years of age. If we look only at recruitment, we will be missing cause-effect relationships leading to year class strength. We must also monitor the young fish.*

How solid is the assumption that young fish inhabit the shoreline?

(Rich Valdez) *The assumption that young fish inhabit the shoreline and shallow, sheltered habitats is probably pretty good. Humpback chub populations have been sampled extensively for 15-30 years with a variety of gear types. Although gears are less efficient in deep water, we have not captured young fish in main channel areas where we have captured adults. For example, we have angled with worms, cheese balls, and salmon eggs in depths as great as 20 m in Black Rocks, Westwater Canyon, Desolation Canyon, Cataract Canyon, and have caught many adult humpback chub, but no juveniles. Also, experimental electrofishing with 15-m long cables in Black Rocks, Westwater Canyon, and Cataract Canyon have yielded adults but not juveniles. We have also tried otter trawls in portions of the upper basin, but these have been difficult to use in canyon reaches. No young fish of any species were caught in mid-channel otter trawls in sandy, alluvial reaches of the upper basin.*

(Bill Persons) *See AGFD backwater studies, Bio/West reports. Read any big river literature on young fish?*

RESERVOIR EFFECTS

Is there any evidence that HBC did better during periods when warmer epilimnion extended down to penstocks? (early '80s) What were downstream temperatures like during those periods?

(Wayne Gustaveson) *Encounters with HBC were more numerous in Lake Powell in the 80's meaning that we did encounter ONE fish in the reservoir. There is absolutely no evidence that HBC have ever done "well" in the reservoir since Lake Powell was impounded. I don't have temperature data but feel temperatures were consistently running out of the dam at/near 46 F.*

*(**Susan Hueftle**) While the warming resulting from the large inflows penetrated to the penstock depths, the peak of these warmest releases occurred in December, as they do regularly. During the 80's, temperatures at Lees Ferry were measured up to 12-13/C. Temperatures were sustained from 10-13 /C from about mid-summer to November in 1983, '84, and '86. Spillway releases in 1980, '83 & '84 produced peaks to 13-15 /C for short periods.*

Could some stable isotope experiment be done to determine food source? (autochthonous vs. allochthonous?) Would there be value in that? Thence – what would be the implications for the alternative of epilimnion withdrawal?

*(**Susan Hueftle**) One experiment was done during the spike flood by NAU aquatic biology. However, there is currently great annual variability in amounts of plankton discharged that has not been accessed closely for its contribution to the foodbase downstream. The addition of epilimnetic plankton would increase downstream loading considerably.*

Will a TCD discharge more plankton; how about shad? eggs? Stripers?

(Bill Persons) I assume YES for shad, don't know about eggs or stripers.

(Wayne Gustaveson) *More plankton would be entrained and passed downstream with TCD. Shad would come through seasonally when they were located in the forebay. Withdrawal closer to the surface would enhance plankton entrainment and shad discharge. There should be a direct relationship between depth of discharge and abundance of shad and plankton passage. The higher the discharge the greater the passage.*

Eggs are another matter. Most sport fish species in LP have adhesive eggs which will NOT transport. Striped bass are the exception. They are surface spawners but fertilized eggs descend at a rate of 1 foot per minute. Therefore, striper spawning must occur in close proximity to the dam or eggs must settle on a discreet density current layer that would transport eggs to the dam. Most striped bass spawning occurs in the backs of canyons - not the main stem where density current transport may be expected. I suspect striper eggs would not often pass. If they did, water temps would need to be above 55-57 F before any fish would survive. Striped bass larvae prefer temps in the low 60's and suffer similar fates (thermal shock) as native fish in lower temperatures. Adult/juvenile passage has only occurred during spillway operation and I expect that to continue.

Smallmouth larvae are bound to the shoreline and not expected to be in contact with density current transport mechanisms. Smallmouth adults or juveniles have not readily passed downstream from the lake in the past decade with deep water discharge. Surface withdrawal increases the likelihood of transport but not so much that I would expect any significant response.

*(**Susan Hueftle**) The greatest concentrations of plankton are in the top 20-30m of the lake, epilimnetic withdrawals will entrain more epilimnetic organic matter.*

Do dam operations really affect the heat budget of the lake? i.e. does the model show a difference in thermocline depths with and without release of water?

(Amy Cutler) *I assume this question is referring to whether the CE-QUAL W2 model indicates a difference in thermocline depths with and without the use of TCD. The model shows a 20% reduction in thermocline depth during the months of June though October with the use of TCD over a four-year simulation.*

(Wayne Gustaveson) *The model shows only a one degree C drop in temp with TCD. I have no reason to dispute these predictions. I am not sure how the thermocline depth would differ.*

*(**Susan Hueftle**) Unquestionably dam operations have the potential to affect the lake's heat budget. The lake's temperature is dependent on decadal climate cycles that have delayed and prolonged effects. Long-term heat content of the reservoir has been defined by the thickness and temperature of the epilimnion resulting from the spring flood, and much less by surficial warming of the lake. The selective discharge of this layer could change the lake's heat budget **depending** on the timing and duration of the TCD's use. Dam*

operations themselves can influence the dimensions of various layers as discharge determines the vertical extent of the withdrawal plume. The significance of that effect on the reservoir is unknown, but the model should be able to tell us in terms of heat content.

SYSTEM EFFECTS

Were there any observed effects this summer in riparian resources?
(Bill Persons) *Tremendous response of tamarisk on wet sand beaches.*
(***Joe Shannon***) *Tamarisk seedlings were abundant by Sept., but were removed by the fall flows in all reaches but Glen Canyon. This tamarisk response occurred through out the drainage, probably because of the low run-off for 2000.*

What is the relationship between peaking operations and wave dampening as the waves move downstream? (i.e., what's an "acceptable" range of peaking power for minimizing wave effects downstream?)
(***Joe Shannon***) *During the 1995-1997 period of relatively high/steady flows, daily fluctuations of <4k cfs produced minimal stage changes. Due to habitat stability, the benthos grew as did the those pesky trout throughout the study site.*

How much nitrogen and phosphorous are used in the Colorado River? Down to Lee's Ferry? (***Joe Shannon***) *Nutrient cycling information is zero, but should be quantified prior to the TCD so we can understand cause/effect.*

The concentration of nutrients could decrease, but the mass load of nutrients are likely to remain relatively high. What controls the productivity in the river…concentration of nutrients or mass of nutrients?

What is the relationship between habitat in the river in various segments and GCD discharge (to the nearest 500 cfs)?
(Dennis Kubly) *Some evaluations of habitat-flow relationships have been conducted. See for example: (1) Persons, W. R., K. McCormack, and T. McCall. 1985. Fishery investigations of the Colorado River from Glen Canyon Dam to the confluence of the Paria River: assessment of the impact of fluctuating flows on the Lee's Ferry fishery. Federal Aid Report F-14-R-14. Arizona Game and Fish Department (2) Valdez, R.A. and R.J. Ryel. 1995. Habitat. Chapter 7 in Life history and ecology of the humpback chub (Gila cypha) in the Colorado River, Grand Canyon, Arizona. BIO/WEST, Inc., Logan, UT.*

Reduced nutrients with TCD in place? Could this mean we go from Temperature – limited productivity to nutrient – limited productivity?

(Dennis Kubly) *(1) I think that GCMRC nutrient sampling in the forebay indicates lower concentrations of dissolved nitrogen and phosphorus would be present in higher elevation withdrawals. I do not know whether the total concentrations of particulate and dissolved forms have been evaluated. More particulate nitrogen and phosphorus would be delivered through TCD inlets as plankton and detritus. (2) I do not know of any evidence that productivity presently is temperature limited..*

POLICY

The ROD calls for operating GCD to achieve "recovery and long-term sustainability" of biological resources. Shouldn't this ROD "basis of decision" be a guiding principle for monitoring?

(Rich Valdez) *This is correct. Also, recovery goals for the four endangered fishes of the Colorado River (Colorado pikeminnow, humpback chub, razorback sucker, bonytail) provide criteria for recovery, and specify monitoring periods of 8 years for humpback chub with estimates of abundance (mark-recapture population estimates) to determine status and trends. These should also be guiding principle for monitoring.*

QUESTIONS TO PRESENTERS

For Barb: Monitoring has been done in Grand Canyon since the 1980s; what trends are apparent? What have we learned from these data about trends? Can these data be used to guide monitoring strategies?

(***Barb***) *There is a belief that monitoring has been done in Grand Canyon for all resources since the 1980's. I would say that that is not true. Data collected in the 1970's, 80's and into the 1990's prior to 1997 involved surveys of what was in the system followed by research to address questions. Some resources had data collection efforts that were long term that can be used to determine trends in the system. One of these is the Lees Ferry trout fishery ((McKinney and Persons 1999). The trends show that there are three distinct timeframes associated with the fishery: 1965-1984; 1984-1991; 1991 to present. There was a shift in the trout fishery after the 1983 floods from a fishery with many large rainbow trout (>400 mm) to one with a few large trout and many mid-range trout (250-350mm). The numbers of fish have increased, while size of fish has decreased. For other fish resources, fish studies have been undertaken in parallel with the Lees Ferry rainbow trout program. These data consist of relative abundance data for fish in a synoptic effort over time. Because the data collection effort did not take into account gear efficiencies, getting estimates of population change for all fish species is not possible. We do have an estimate for humpback chub that indicates that the numbers have not decreased since the 1993 estimates of Douglas and Marsh.*

More recent data collection efforts for brown trout indicate that the range for brown trout has increased upstream and downstream. How this plays into interactions with native fish or other fish we do not have a clear idea about. Brown trout are a major predator in many systems, so one can guess these fish may be having an effect on other fish species. The degree of its affect are unknown, though.

Other resources like the foodbase indicate that things have changed from a single dominant algal component, Cladophora, to a more complex suite of constituents. If this is operational affects, foraging affects or a combination of these is unknown.

There are similar parallels in the terrestrial side of things, but the level of measurement has been at a less intensive effort.

With respect to using these trends to guide monitoring programs. We are using these in combination with recognition of what is biologically significant to measure and at what scale does one measure response for monitoring. A question is at what point does one determine a trend as significant vs. natural variation and what action does one take? System-wide questions regarding trends and existing data may be at a point where single year response data may feed into our need to know change. Local response, or data regarding single species may require a longer time period for response.

What is the difference between monitoring and research?
(Barb) *Monitoring collects data on demographics or other parameters that measure the health of a system to determine if the system is responding positively or negatively to some anticipated outcome after some treatment is imposed. It looks at long-term change over a variety of treatments. The AGF 1999 synthesis is an example of reviewing response of an organism over time.*
Research takes those data but examines the mechanisms or causal relationships of that negative or positive response.

For Dennis: Can you conduct habitat maintenance flows and maintain warm outflow?
(Dennis) *Habitat maintenance flows, as identified in the Glen Canyon Dam Environmental Impact Statement, were intended to be "high steady releases within powerplant capacity (33,200 cfs) for 1 to 2 weeks in March, although other months would be considered under adaptive management." Warm releases could not be delivered in March, with or without TCD modification. In later months, our ability to deliver a given water temperature would depend on the number of high elevation inlets available, the reservoir elevation, and the amount of dam release. Since each intake can deliver a maximum of ~4,000 cfs, modifying less than all 8 inlets could affect our ability to maintain constant temperature during habitat maintenance flows (and beach habitat-building flows).*

It seems as though data analyses are lagging behind where it might be. With all due consideration of principle investigators, perhaps separate contracts could be issued for particular data analyses which may have a bearing on temperature control structure issues. What do you think? What data is out there? Is there a comprehensive list?
(Dennis) *After the TCD workshop in November 1999, GCMRC rechanneled funding for native fish work away from field investigations and into data accumulation, database management, data analysis, and synthesis. My understanding is that all fish data gathered*

since 1990 are now held by GCMRC. Some of that work is being done by previous investigators, some by new investigators, and some by GCMRC staff. I do not know what analyses have been conducted on those data. Bottom line: Assuming we address concerns of principle investigators for publishing their work, I think this is a good suggestion.

For Josh: Does P/F relationship to age I recruitment consider likely increases in metabolic requirements of predators?

(Josh) *If metabolic demand increases, the effective 'P' will increase. This additional dynamic is not incorporated in the model as bioenergetics is not explicitly modeled. There is no point in dealing with this additional dynamic given the insufficient data to use the model at its current level of complexity.*

What is the status of data and modeling efforts on native fish?

(Josh) *See the summary of my presentation in this document. Also the following references can be consulted:*

Walters, C.J. and J. Korman. 1999. Linking recruitment to trophic factors: revisiting the Beverton-Holt recruitment model from a life history and multispecies perspective. Rev. Fish. Biol. Fisheries. Vol 9: 1-16.

Walters, C., J. Korman, L. E. Stevens, and B. Gold. 2000. Ecosystem modeling for evaluation of adaptive management policies in the Grand Canyon. Conservation Ecology 4(2): 1.

What are the bottlenecks?

(Josh) *Not sure of the meaning. Bottlenecks for what, native fish production, chub production in the mainstem Colorado? The question needs to be formulated more explicitly. We talked extensively at the workshop about various hypotheses potentially controlling chub production (mainstem spawning, early juvenile survival of fish emigrating from the LCR).*

How can the bottlenecks be resolved?

With reference to the conceptual model: have "risk" analyses been applied to the modeling evaluations to see what the likely response of humpback chub would be to temperature changes?

For Amy: Does alternative II variable level intake on 4 tubes consider frequency and duration of having a turbine down for maintenance?

(Amy) *In our studies we looked at scenarios which included structures modified with two, three and four TCDs and compared them to an all-modified scenario and one without any TCD. The scenario with four modified intakes did not include the possibility that a structure would be down for maintenance. The case of three modified structures allowed that one of the four structures able to be worked on for maintenance. Referring to the handout graph* *on this study, the release temperatures were very comparable between the above two cases except for 1995.*

Does flexibility in release temperatures under preferred alternative allow the kind of experimental design suggested by Josh?

(Amy) *Not sure what is meant by "preferred alternative" with reference to the TCD. The most complex engineering design for a TCD considered in the first environmental assessment allowed withdrawal of warm water in a 130 foot range of reservoir elevations at a cost of about $150,000. All designs are compromised to some extent when the reservoir is too high or too low. Nevertheless, there should be enough flexibility (and control over) in water temperatures with a TCD to test predictions of the conceptual model.*

What are the biological effects of cooling Lake Powell?

(Amy) *From our study we see a small change in the overall heat budget, in my opinion, I don't think that this will effect the biological system that much.*

With a 4 outlet alternative will water mix downstream? How do you assess?

(Amy) *To answer this question I will pick an extreme condition where you are releasing 8° C water from the penstock elevation and 15-20 °C from TCD inlets. In that situation, you might have some lateral and vertical stratification persisting through the Lees Ferry reach. The next version of CE-QUAL, due out this autumn, will be able to address this type of analysis.*

I assume the temperature modeling uses a monthly time step? If so what effect if any do hourly varying releases have on your results?

(Amy) *CE-QUAL W2 uses varying timesteps allowing us to observe hourly varying releases.*

For Susan: What is the expected effect of lower nutrient concentrations in discharge from a TCD?

(**Susan**) In the lake, sustained operation of a TCD could shift the distribution of chemicals, including nutrients. A well calibrated model should be able to allude to this question, if not reveal the subtle biological processes that influence it. Should the hypolimnion become more concentrated as a result of preferential routing of the epilimnion, we might see the reservoir become more productive over time. It would probably take many years of operation to change the reservoirs oligo/meso-trophic status to eutrophic. However, depending on how the spring flood is affected by TCD operations, an alternate interpretation might suggest increased routing of clay-bound phosphorus with the epilimnetic withdrawals. This could produce somewhat higher P as well as epilimnetic particulates discharged downstream. Modelling may answer this question, but it may take its operation to determine for certain.

The downstream effects would most likely be felt in the Lees Ferry reach. Below that, light is a more significant limiting factor than nutrients, although this should be tested. This change in the physical and chemical water quality (regardless of the direction), along with an altered flow regime, could result in a shift in the riverine phyto-benthic community, with unknown effects to the rest of the food web. If there were less nutrients, it could limit productivity in the tailwaters. Are there any plans to develop predictive models of thermal and physical processes in the Lake? Why do I ask? Because, if these processes are important and could be affected by a TCD, we need some predictive capability.

(***Susan***) *The CE-QUAL W2 model that Amy Cutler and BOR are working on should be capable of predicting most of the major thermal dynamics required for the operation of the TCD. It will also be able to handle other dynamics for major components, such as hydrodynamics and dominant ion concentrations. Like any model, it is less likely to reliably predict complex biological processes. GCMRC hopes to adapt this same model for its own efforts in the future.*

For Joe: If we increase temperature and decrease upright diatoms, what will happen at other levels of the food chain? How will we measure?

(***Joe***) *We have not been able to find any reports in the literature about this. In order to maintain the same levels or to increase the biomass of bugs we would need colonization of non-epiphyte grazing bugs. The post-dam midge colonization took over 20 years and is still continuing (neo-tropic to nearctic)*

We could detect changes in the macroinverts with our standard benthic protocols, which does pick-up rare taxa. All the diatom info has come from explicit research questions, but this could be added to long-term monitoring.

Is there really a temperature effect on benthic diversity?

(***Joe***) *Temperature/diversity relationships have been well documented by Vannote and Sweeny with their Thermal Equilibrium Hypothesis. Cool or warm stenothermic aquatic habitats are high in biomass and low in taxa richness because developmental cues are missing for the aquatic insects to complete their life cycles. Yes, consistent seasonal cooling of the river, to increase the thermal range, may enhance the aquatic community.*

For Rich: What are advantages and disadvantages of a fixed sampling site approach?

(Rich) *A fixed sampling site approach works well for humpback chub because of the high fidelity by individuals and populations for very specific reaches of river. Radiotelemetry and tagging studies in all six populations consistently show that adult humpback chub move less than 2 km over periods of 1-8 years. If the objective of monitoring humpback chub is to quantify the status and trend of the population, sampling those reaches in which* *the fish does not occur or is rare, is a waste of time and money. Synoptic sampling can be conducted in areas other than aggregation centers to detect dispersal or range extension.*

Is stomach pumping effective for humpback chub?

(Rich) *Yes–several stomach pump designs were tested on 40 wild surrogate roundtail chub in the Upper Colorado River Basin (Wasowicz and Valdez 1994) and used on 168 wild humpback chub in Grand Canyon (Valdez and Ryel 1997). Tests with roundtail chub showed no damage to the gullet or the pharyngeal mill. Pumping of wild humpback chub indicated no adverse effects (fish were recaptured at a later date), and we had problems extracting gut contents from only one fish that had swallowed a large sunflower seed.*

Valdez, R.A. and R.J. Ryel. 1997. Life history and ecology of the humpback chub in the Colorado River in Grand Canyon, Arizona. Pages 3-31 In: van Riper III, C. and E.T. Deshler (eds.). Proceedings of the Third Biennial Conference of Research on the Colorado Plateau. National Park Service Transactions and Proceedings Series NPS/NRNAU/NRTP-97/12, Flagstaff, AZ.

Wasowicz, A. and R.A. Valdez. 1994. A nonlethal technique to recovery gut contents of roundtail chub. North American Journal of Fisheries Management 14:656-658.

(Bill Persons) *Talk to Dennis Stone (F&WS Flagstaff), he had some concerns about it after some experiments done on chub in the hatchery (evidently he fed them trout and could not lavage the trout back out*.

(***Joe Shannon***) *Diet analysis through gut content alone is not a very accurate method of assessing fish diet. Assimilation, not ingestion, is the key here, stable isotopes and antigen techniques remove the behavioral biases. If fish only consumed digestible food then how do you explain the artificial lure industry?*

Short term monitoring - how much lead time would you need to monitor a spike?

(Rich) *A 1-month lead time would be sufficient to get crews together and equipment lined out and in order. The problem is not often getting crews together, but getting contracts in place and river permits. If a group was on contract and on standby, with equipment available and ready, 2 weeks lead time would be all that is necessary to launch a monitoring trip for a spike flow.*

(***Joe Shannon***) *60 days is more realistic. The science river permit system takes 45 days at a minimum without alot of NPS cooperation. I do agree that the contract is the key ingredient here and long term monitoring should have a funding trigger to get these types of collections started.*

Does the need for humpback chub population estimates drive the long-term monitoring program to the detriment of a more robust monitoring program; will we spend too much effort trying to answer one question and miss others?

(Rich) *Knowing the abundance of a target resource over time is the most important parameter in long-term monitoring. The endangered humpback chub drives much of the outstanding elements of the reasonable and prudent alternative of the biological opinion. Periodic estimates of absolute abundance are needed to evaluate response to management actions and assess recovery status of the species. Monitoring programs that measure many parameters are not more robust, but less. Programs that strive to measure all related parameters in an ecosystem tend to dilute the precision and accuracy of individual measures of structure and function because the numbers of study programs are often limited by funding and logistics; this is certainly the case in Grand Canyon. Monitoring the abundance of humpback chub must be a priority for the monitoring program. Monitoring of other parameters needs to be prioritized according to program objectives, but the reality is that we will not be able to monitor all resources, even those some might consider to be vital. Ecosystem models and stock synthesis models may provide a better understanding of relationships among variables, but these provide only general inferences into status and trends of given resources and may not be sufficiently precise to attribute biological responses to specific management actions as cause-effect relationships.*
Because of the relatively stable nature of the adult portion of humpback chub populations, multiple mark-recapture estimates of abundance need to be done only once every 2-3 years, but relative abundance estimates are needed annually to assess year class strength. The best success with abundance estimates of adult Colorado pikeminnow and humpback chub in the upper basin is three to four passes spaced a few days to a month apart (i.e., one initial capture event followed by two or three recapture events). A two catch effort (Peterson estimator) might work if we can put enough effort into the two catches and there is not a lot of fish movement between the LCR and mainstem. C. Walters has suggested that we do concurrent estimates in the mainstem and LCR and use stock synthesis models to determine actual population size.

For Wayne – Could TCD operations selectively discharge non-natives downstream?
(Wayne) *Shad would be the most likely fish discharged. I do not think stripers or smallmouth would be discharged except for a few individuals that would pass on an irregular basis. The warmer the water/shallower the discharge the greater the chance of passing sport fish downstream.* ***Hydroacoustic sampling*** *in the forebay would enhance our knowledge of what is expected to be passed downstream.*

What is the status of population modeling in the lake? Can/should we undertake this?
(Wayne) *I would support attempts to add fish and plankton to the physical/chemical model that has been used already. There have been no population models constructed in the past to my knowledge.*

For Joe Shannon: Was the warming that occurred in 1983-84 (80) with spillway discharge monitored? Any effects? If so, anything that could be separated from high discharge? (increase 60 to 90 Kcfs). Comment– if these food base issues are important, we need quantitative assessments and predictive capability.
(***Joe***) *There are no data sets for this time period. I would suspect that the flows would mask and thermal effects anyway.*

For Bill Persons: I am impressed by the modeling progress you have made. (From DH)
(Bill) *Thanks, the real credit goes to Carl Walters and Dave Speas.*

Can we devote some joint effort to linking an economic model to this population work? How is this accomplished in GCM model now and how could this be improved?
(Bill) *We'd be interested in seeing this done, right now the GCM model seems to do it, but you would have to check with Josh on the specifics of the math behind the model.*
For Lew Coggins: What is the current status of your population modeling effort?
(Lew) *We are early on in the process and still evaluating the best estimation methodologies. We expect to have a draft model and early results by August 2001.*

Could this be accelerated with additional resources or assistance?
(Lew) *Yes. Particularly access to another person with strong quantitative fisheries skills.*

What data are available?
(Lew) *GCMRC now has all of the LCR and Mainstem data collected after 1990. Some of it is still in the process of being edited and merged into the GCMRC data base.*