Report of the 2009 Protocol Evaluation Panel for Fish Monitoring Programs of the Grand Canyon Monitoring and Research Center

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Executive Summary

In May, 2009 a panel of seven scientists was convened to review fisheries monitoring programs in the Glen and Grand Canyon reaches of the Colorado River as part of the Grand Canyon Monitoring and Research Center's (GCMRC) Protocol Evaluation Program (PEP). The review is the second for these programs. Earlier reviews were conducted in 2000 and 2001.

The Panel was impressed by the quality of work being conducted on the Colorado River and its tributaries: that quality is reflected in the number of scientific reports, theses and refereed journal publications that have resulted from the program. Since the first PEP reviews, much has been learned about monitoring and strengths and limitations of each program component.

The over-arching recommendation of the Panel is that since a number of years of data collection have taken place it is time to review the information collected to date to evaluate the current program and inform future changes. A list of management objectives has been developed for the river and its resources and a list of corresponding information needs are also in place. The Panel believes that more explicit linkages between data collected from field programs and information needs and objectives should be developed. After this evaluation is completed, the Center will be in a position to reallocate resources to those that are in need of further development.

Introduction

The Grand Canyon Monitoring and Research Center (GCMRC) is responsible for a program of monitoring and research of natural resources in the Glen and Grand Canyons of the Colorado River, and for the evaluation of the effects of operation of Glen Canyon dam on those resources. One component of its activities is a regular program of independent peer review of the research and monitoring programs.

This report documents findings of the 2009 Protocol Evaluation Panel (PEP) charged to review fish monitoring programs in the Glen and Grand Canyon regions. This PEP is the second to evaluate these programs: the Lee's Ferry monitoring program was reviewed in 2000 (Culver et al. 2000) and fish and aquatic science programs in the Grand Canyon were reviewed in 2001 (Anders et al. 2001). Members of the 2009 panel and their affiliations are listed in Appendix 1.

The 2009 PEP review was conducted in three stages. The first stage consisted of presentations and discussion of the background context and each component of the fisheries program at the GCMRC facilities (May 8) and at Marble Canyon (May 9). The second stage consisted of site visits in Glen Canyon (May 10) and the Lee's Ferry to Little Colorado River (LCR) region of the Grand Canyon (May 11-May 14). During site visits, discussions and informal presentations were made with program PIs and sampling activities were observed in the Colorado River and the LCR. The panel returned to Flagstaff on May 15. During the third stage, the Panel reconvened in Flagstaff during May 16-17 to consider its findings and to develop a draft set of recommendations and conclusions. These preliminary findings were presented to the Adaptive Management Program Technical Working Group (TWG) on June 22, 2009 in Phoenix and are finalized in this report.

The PEP was guided by an overview document that provided an outline of each component of the program and a series of questions that were generated by the TWG (Appendix 2). Based on that document, the PEP organized its findings into five main elements:

1. Overview and institutional matters;
2. Monitoring of rainbow trout and other fishes in the Glen Canyon reach ("Lee's Ferry" trout program);
3. Monitoring of humpback chub in the Little Colorado River;
4. Monitoring of native fish in the Colorado River between Lee's Ferry and Lake Mead; and
5. Monitoring of non-native or invasive species in the Colorado River.

The format of the review is similar for each program element. The panel's general findings are presented first, followed by recommendations and responses to questions from the TWG.

1. Institutional

Since the last PEP panels, considerable progress has been made in the development of monitoring and assessment programs for fisheries resources in the Glen and Grand Canyons. A large body of data and reports has been amassed. As is commonly the case in these situations, the annual cycle of contracting, sampling and reporting can overwhelm the responsible agency to leave little or no time for integration and analysis over time or among program components. The Panel felt that each program would benefit from a careful review to address key questions:

- What are the objectives and information needs that relate to each program?
- What data will be used to address progress to the management objective and
- How precisely must parameters be estimated, and what is the minimum level of effort needed to satisfy that level of precision?

The Panel felt that addressing these questions would allow development of assessment frameworks for each sampling program.

Like earlier review (Anders et al. 2001), the Panel expressed concern about the Adaptive Management component of the program. A successful Adaptive Management program requires a carefully designed, sustained experimental regime with treatments that significantly perturb the system to elicit a detectable response. The Panel was unclear as to whether those conditions were in place.

Recommendations

1. In most cases, monitoring programs are beyond the experimental stage and considerable experience and data have been acquired. GCMRC should now be able to develop a standardized framework for archiving data and reporting of monitoring results for key program elements. This structure would allow data and results from individual contract reports to be synthesized and organized to report on CMINs and management objectives. Maximum success of this approach depends on full participation by all cooperators and researchers working in the system. Currently, some impediments (both real and perceived) prevent timely and complete data sharing among some cooperators. These impediments should be identified and alleviated. For example, the USGS critical review process overly jeopardizes partnerships and cooperative relationships with other Department of Interior agencies and slows the response time of GCMRC. In some cases, formal agreements such as Memoranda of Understanding may be useful mechanisms to circumvent interagency policy conflicts (e.g., among sister agencies under the DOI).
2. Any effort to recover an endangered species must by necessity take a long-term view. Numerous lines of evidence suggest that the Colorado River System will undergo substantial change over the next 50 years and beyond, both natural and anthropogenic, that will affect key characteristics of the system, particularly water availability and temperature. Development of management strategies for system conditions that occur or can be created currently, but that will no longer exist or be feasible several decades from now, will provide little or no long-term benefit. We recommend that the AMWG and GCMRC convene a group of experts to advise them on likely future trends in conditions that will affect the Colorado

River system (e.g., changes in temperature and precipitation, water withdrawals and diversions, reservoir levels, etc.) and use that information to identify probable bounds on management options for the future. Even if (perhaps especially if) those options are different than what seems optimal today, agencies should begin testing management scenarios now that are suited to conditions in the long-term to be prepared when those changes occur, rather than managing to avoid risks now that are going to become highly likely in the future.

3. Successful adaptive management requires that the magnitude and duration of management manipulations be sufficient to generate an effect size in the variable(s) of interest that can be detected by ongoing monitoring efforts and differentiated from natural variation. Despite the size and complexity of the Grand Canyon system and the extraordinary logistical challenges to sampling, the rigor of the fish population monitoring program in the Grand Canyon is unprecedented. Coupled with this monitoring effort, the initial 16-year plan to manipulate predation pressure, temperature and flow in 4-year blocks seemed likely to meet these criteria for success. Even though drought-induced temperature increases occurred simultaneously with the predator removal treatment, modifications to the long-term plan could still impose treatments of sufficient magnitude and duration to be informative in parsing the effects of these key variables on the system. All partners should act in consultation and cooperation with each other to maintain an effective adaptive management strategy. Otherwise, even the most accurate and precise monitoring program will have little chance of confidently identifying the ultimate, or even proximate, mechanism(s) driving observed change. We recommend that AMWG members participate in a Bayesian Belief Network exercise, or similar effort, to solidify their goals and reach consensus on how best to achieve them, in a way that takes into account their disparate individual needs, concerns and responsibilities.

2. Lee's Ferry (Glen Canyon) Monitoring Program

Management objectives for the Lee's Ferry reach are to maintain a recreational fishery in the reach while limiting impacts of rainbow trout on native fish that might arise from downstream dispersal. Progress towards these management objectives are evaluated by a creel survey, and an extensive monitoring program for adult and juvenile rainbow trout in the Lee's Ferry reach.

The current monitoring program for rainbow trout in the Glen Canyon started in 1991 using 15 fixed sites that were sampled with boat electrofishing 2–4 times per year. The 2000 PEP recommended that sites be reduced in size, increased in number, and selected randomly. Following on those recommendations, a combined program of nine historical fixed sites and 27 randomly selected sites are currently being sampled. More recently, electrofishing for estimating abundance of age-0 fish has been used as a tool to evaluate effects of dam operations on recruitment.

The Panel was very impressed with the quality of information generated by the Lee's Ferry program. The creel survey is unusual, with only one access point for the fishery, so a high sampling rate is attainable. The electrofishing surveys cover >30% of available habitat, a high sampling rate compared to most fisheries. The average annual CPUE is very precise because of the high sampling intensity. Strong covariation in CPUE between random and fixed sites suggests that some reduction of sampling intensity may be warranted. Investigators are to be credited for running both sampling regimes for 9+ years to establish this relation.

The Panel felt that management objectives should be clarified to assist in refining the program. If management goals were oriented to maintaining desirable aspects of the recreational fishery, low mortality resulting from a largely catch-and-release fishery suggests that detailed population sampling may not be necessary, because trends are revealed by angler catch rate and perhaps a less intensive relative abundance survey.

The historical and current annual program is not designed to address the population target, which is expressed in terms of absolute abundance in current management goals and corresponding CMIN. The Panel did not agree that an effort to estimate the absolute abundance would be helpful to managers of the sports fishery.

Another apparent objective of the program that does not appear in the management objectives is to determine the impact of dam operations on recruitment dynamics of the trout population. The Panel thought the current information was somewhat underutilized because age structures were apparently collected but the results were not reported in the most recent Annual Report. A recruitment indicator could likely be developed from available information by separating juvenile and adult data for CPUE calculations. Timing of electrofishing surveys could likely be adjusted to maximize utility of juvenile catch information contained within the ongoing boat electrofishing program.

The Panel was impressed with recent studies on recruitment of age-0 trout in the reach. We were not sure if this information was needed for management of the trout fishery, but certainly provides more detailed insight into flow-recruitment studies. As with other components of the program, clarification of management goals would assist in determining whether continuing this program on an annual basis is needed for management objectives.

Recommendations

1. Recast management objectives as angling catch rate, rather than absolute abundance, to frame the management program more directly in relation to the current catch-and-release angling fishery. If the fishery develops into a trophy fishery (e.g. through flow regulation), management objectives could be changed to better reflect a harvest-based fishery (e.g. catch or harvest of trophy-sized trout).

2. Retain the creel survey to monitor annual fishery performance and angler satisfaction in relation to revised management objectives. Under the current catch-and-release fishery, angling catch rate is the best metric for monitoring fishery performance. If the nature of the fishery changes, alternative angler-based metrics may be required.
3. Evaluate the effect of reducing electrofishing effort from 3–4 trips per year to 1–2 trips per year and eliminating fixed sites from the survey design to provide an index of trout population density based on random sites only. Effort to sample fixed sites can be redirected to surveillance for non-native fishes at likely locations (e.g., the 'carp pond' or location of previous smallmouth bass catches) and increasing the number of random sites within a trip. A power analysis suggests that reducing sampling effort by one half would only minimally impact precision. Metrics from this part of the survey provide a frame of reference for trout in downstream reaches and a means by which to evaluate the degree to which trout migrate downstream. Growth rate can be estimated from ongoing age estimation, rather than tag-recapture data. More use of age information is recommended to develop year-class strength indicators.
4. Monitoring age-0 trout habitat use and movement is not routinely needed because the electrofishing survey provides a direct index of pre-recruit trout density. Similarly, redd counts are not needed because the electrofishing survey provides a direct index of adult trout density. This program's strength is in evaluating the impacts of flow manipulations on early life history, and it should be part of the evaluation of future flow tests.

Responses to TWG Questions

1.1. Are the current monitoring methods providing the information that managers need to manage the fishery, or should different metrics be pursued?

- Harvest on the population is virtually nil, management requirements for the fishery are not great.
- Management objectives for the rainbow trout fishery should be recast in terms of angling fishery attributes, such as catch rate (number per angler hour) or fish size.
- Monitoring methods provide precise estimates of relative abundance from fishery dependent (creel survey) and fishery independent (electrofishing survey) surveys.
- Electrofishing surveys provide additional estimates of size structure (indexed as PSD), body condition (indexed as relative condition), and growth (estimates not provided) and presumably age structure.
- Trends in relative abundance indexed through creel and electrofishing surveys are consistent, which suggests that trends in population density are indexed accurately.

1.2. Is the current sampling design sufficiently robust enough both spatially and temporally to monitor a change in status and trends in the distribution, condition, and abundance of rainbow trout?

- The current sampling design provides annual estimates of fishery attributes throughout the Lee's Ferry reach of the river, but is probably more intensive than necessary.
- The power analysis suggests that reducing electrofishing effort from 3–4 trips per year to 1–2 trips per year would still provide an adequate index of trout population density and recruitment, with only small impact on precision.
- Comparison of fixed and random sites indicates that both designs provide similar indices of population density and suggests that both are not needed to accurately index trends in population density.
- Therefore, the random sampling design should be retained and the fixed sampling design can be eliminated (saved effort can be reallocated to other parts of the monitoring program).

1.3. Are standard measures of relative abundance, e.g., catch rate, suitable surrogates for calculating absolute annual abundance? What are the relative risks of using CPUE instead of determining annual abundance? Does the PEP panel recommend that absolute annual abundance is needed for managers to make management decisions?

- Catch rate is a suitable surrogate for indexing abundance if catchability is proportional to population density, so the relationship between catch rate and population density must be examined for non-linearity.
- Risk of using catch rate instead of absolute abundance is related to non-constant catchability (i.e., hyper-stability or hyper-depletion), where catch rate declines more or less rapidly than population density as density declines.
- Absolute annual abundance is not needed for managing the fishery if management objectives are recast in terms of angling catch rate and if catchability is proportional to abundance. This assumption cannot be explicitly tested because annual estimates of abundance are not available. Some elements can also be examined by comparing angler and electrofishing CPUE and considering whether gear saturation occurs at high densities, or if searching behaviour by anglers occurs at low trout densities. The latter is likely in a recreational fishery.

1.4. Should a greater emphasis be placed on young-of-year rainbow trout survival, growth and recruitment in this monitoring program?

- Monitoring age-0 survival, growth, and recruitment is needed only if management objectives require such knowledge. The Panel suggests that management objectives should be reformulated in metrics appropriate to a recreational fishery, which generally do not include juvenile life stages.
- Recruitment can be indexed through the ongoing fishery independent sampling program, so added survey effort focused on juveniles is not necessary to meet this objective. Better use of age information could result in the development of a recruitment indicator from the ongoing electrofishing survey.

- Juvenile recruitment dynamics may need to be understood if management objectives for the population include addressing impacts of flow manipulation on early life history, including attempts to manage the population using flow.

1.5. Is the frequency of Lees Ferry rainbow trout population monitoring suitable for addressing the CMINs?

- See response to question #2 above.
- Surveying the reach 3–4 times each year is not likely needed to adequately monitor status and trends of the trout population in the reach.
- Less intensive survey effort will likely be sufficient if the objective for the survey is changed from estimation of absolute abundance to indexing relative abundance. This is especially the case if harvest on the population is negligible and if angler and electrofishing catch rates are sufficient for evaluating long-term trends.
- Simulation studies can be used to determine the required amount of sampling. The stated goal of a Coefficient of Variation (CV) of 10% is far more precise than most assessments, whereas 20% is often considered as more than adequate.
- If fixed sites are eliminated from the sampling program, some effort can be reallocated to surveillance for non-native fishes (e.g., sampling the 'carp pond', location of previous smallmouth bass catches) and the remainder used to increase the number of randomly chosen sites sampled per trip.

1.6. What is the best way to monitor downstream movement and fate of rainbow trout? What is the best way to determine if downstream movement is density dependent, or dependent on some other factor?

- Downstream movement can be monitored by tagging trout in the Lee's Ferry reach and then modeling recapture rates of tagged fish in downstream reaches.
- To enable modeling of movement, numbers of fish tagged must be large enough to ensure enough recaptures are observed in downstream reaches. Current sampling effort is not likely sufficient to tag adequate numbers of fish for modeling density dependent movement from Lee's Ferry to other reaches of the river. Therefore, a power analysis should be undertaken to determine the number of fish that would need to be tagged annually to estimate movement into downstream reaches.
- Alternatively, downstream movement can be inferred by comparing catch rates of trout species between the Lee's Ferry reach and downstream reaches sampled during mainstem Colorado River monitoring (see below).
- Existing information may be adequate to evaluate density-dependent movement by 2010 if the apparently large 2008 cohort survives. Age-specific catch rates in Lee's Ferry and in the 0–60 mile reach can be compared to determine if abundance in Lee's Ferry is non-linearly or proportionally related to abundance further downstream.

- In addition, tagging, rather removing, fish in the control reach of the mechanical removl project may provide information that can be used to identify rates of immigration into the removal reach from upstream or downstream.

3. Native Fish Monitoring

This section primarily focuses on monitoring of the humpback chub (HBC) population in the LCR and LCR reach of the Colorado River. The HBC is the fish species of greatest management concern in the Grand Canyon and has been a subject of intensive investigation for over 20 years. At the time of the 2001 PEP review, the Center was in the process of establishing a formalized monitoring program for HBC, and was beginning to develop a capture-recapture model for the population using information from PIT tags.

Currently, the Center runs a variety of programs to assess the status of the HBC population. The abundance of fish in the LCR is estimated using closed population mark-recapture models in spring and fall, and an index program that continues a long-standing database each spring in the lower reach of the LCR. In the mainstem, HBC are sampled with a somewhat ad-hoc hoop net program and are captured incidentally in electrofishing and other surveys. Captured fish are PIT tagged and their recaptures form the basis for the "age-structured mark-recapture" (ASMR) model that estimates current population size. The model also generates estimates of past population abundance and recruitment.

In reviewing reports from the various programs, the Panel concluded the HBC program would benefit from development of an assessment framework, similar to what is used for commercial fish stock assessment, as a means to combine and integrate data sources. We noted that no formal process exists to put results in a consistent format for comparison, and in some cases, output from reports were too different to allow comparison. Development of an assessment framework would identify information needs to evaluate status of the population on an annual basis, and each investigator would be required to provide that information on the cycle (annual, biannual, etc.) deemed required.

Recent analysis of the ASMR model indicates that the size-based procedure for estimating year-class strength may not provide precise and unbiased estimates of recruitment. If that component of the model's outputs prove not to be as adequate as empirical measures of recruitment, then the need for regular updates of the model can be reduced because the total adult population will change slowly given the species longevity and correspondingly low natural mortality. Consequently, the Panel believes the ASMR model results do not need to be updated annually and that a 3–5 year cycle would be adequate. Large changes in recruitment or to the adult population can be assessed in "real-time" through field programs.

Following from the assessment framework, the Panel believed more work could be done to assess the *minimum* level of sampling, handling and tagging required to provide information needed for assessment. The Panel heard that minimizing the degree of intrusion into the GCE was an important stakeholder value, and impacts of handling and tagging on individuals are uncertain. Given the low apparent natural mortality of HBC, results of recent ASMR sensitivity analyses suggest that small increases in mortality could significantly alter population trends over the long term. An increasing body of evidence indicates that the expulsion rate of PIT tags can be significant, and recent study has documented long-term impacts of PIT tags on survival of Pacific salmon (Knudsen et al. 2009). While these studies may not be directly relevant to HBC, they confirm a general finding that tag loss and tag and handling-related mortality is generally greater than expected.

The Panel supported further development of a passive PIT-tag array in the LCR. This technology has the potential to replace some intrusive sampling, and can be used to test assumptions of the mark-recapture program, as well as provide an alternative estimate. The Panel was concerned that some of the assumptions of the mark-recapture methodology were violated if fish have fidelity to certain sites and trapping occurs at fixed sites for both samples. A fully randomized trapping design for the second sample (irrespective of the number of fish actually sampled) may be worth considering. A detailed analysis of recapture probabilities is needed to determine the severity of bias (if any) in the program.

The LCR sampling program has generated a large amount of data over the past 10 years and we were not aware of attempts to analyze the results beyond the annual contract reports. For example, results of sampling programs in the lower 1200 m by ADFG and by the FWS in the same reach should be compared. Further, a standardized recruitment series would be useful, for comparison between the ASMR model and various sampling programs.

Recommendations

1. Sufficient information and experience with the LCR HBC population presently exists to develop an assessment framework. This framework would identify information needs and analysis required for managers to assess population status relative to management objectives. The framework would then provide guidance to various programs on the types of information needed from annual reports, and would house all key information in one annual report. Typically, assessment frameworks are peer reviewed, but annual updates are not reviewed unless they deviate significantly from the approved process.
2. In the context of the assessment framework, evaluate spring and fall hoop netting programs to assess the necessity of conducting both surveys. The objective of the fall survey is to provide an index of sub-adult abundance, but spring hoop netting also provides a relative index of sub-adult abundance because length frequency data from spring mimics length frequency data from

the previous fall. Inclusion of the fixed PIT tag array may alleviate the need for fall monitoring. Assessment of the hoop netting program should consider how reducing sampling effort affects the number of newly tagged fish, particularly in smaller size classes.

3. Similarly, we suggest that spring hoop net data from the mark-recapture program be compared to the fixed site 1200 meter hoop net data. The 1200 meter data is a valuable long-term series, but may be redundant to the ongoing spring program. These two programs should be evaluated by comparing catches in the 1200 meter program to data from lower sections of the FWS program. Another option would be to continue the AZGF program, but reduce the FWS sampling in the same reach to avoid oversampling fish.
4. Expand the fixed PIT tag antenna array to span the entire channel and consider deploying antennas at two locations. Spanning the entire channel assists in estimating capture probability and having two antennas allows determination of direction of movement. The PIT tag array may allow detection of movement pathways and habitats used for migration or movement. The array may also inform mark-recapture estimates of the spawning population by better describing the timing of the spawning migration. Our experience elsewhere suggests that arrays may need to be continuously serviced and removed before summer monsoons.
5. Reduce the frequency of ASMR updates from annual to every 3–5 years, unless trends in field data warrant a formal reassessment. Under the aforementioned assessment framework, recruitment can be monitored with empirical catch per unit effort of fish less than 150 mm TL. The LCR adult abundance can be tracked annually using the mark-recapture estimate.
6. ASMR estimates of recruitment do not match hoop net catch rates because of age estimation error in the ASMR. Body parts from the HBC being collected in the nearshore ecology program or as part of disease sampling should be used (e.g. anal fin rays, scales, and otoliths) for *age verification.* Hopefully, verification would allow future non-lethal sampling for age estimation. Age estimates from fish tagged at small size (young "known" age) and recaptured over a wide range of years at liberty should be compared for *age validation.* Sensitivity of the ASMR recruitment index may be increased by using age information in combination with tagging of smaller fish.
7. Management objectives for Chute Falls and other translocations should be specified in measurable terms to guide monitoring and reporting. The panel could not comment on current monitoring activities with available information.

Responses to TWG Questions: Native Fish Monitoring Program

2.1. Are the current monitoring methods and analytical approach employed by GCMRC, AZGFD, USFWS, and other cooperators sufficient to address the CMINs? If not, how should the field and analytical methods be improved to better address the CMINs?

- Current monitoring methods (hoop netting) and analytical approaches (ASMR modeling) are state of the art for the species, especially for the adult fraction of the population in the LCR.
    - Hoop nets are effective for monitoring humpback chub with low incidental mortality.
    - The ASMR model is the best available modeling strategy for available data.
- However, patterns of recruitment indexed through hoop netting and estimated through ASMR modeling are not consistent, evidently because of age-estimation error in the ASMR model.
    - Hoop net catches of fish shorter than 150 mm show strong alternating year classes with dominant year classes in 2002, 2004, 2006 and 2008.
    - Model-based estimates of age-2 recruitment show an increasing recruitment trend, but no biannual fluctuation in year-class strength.
- Age-estimation error in the ASMR model could be assessed by sacrificing some fish for direct estimation of age and growth.
    - Samples (e.g. anal fin rays, scales, and otoliths) should be collected from a sample of fish over the range of observed lengths for *age verification*.
    - Age estimates from fish tagged at small size (young "known" age) and recaptured over a wide range of years at liberty should be compared for *age validation*.
- Current monitoring and analytical approaches are not likely sufficient for the mainstem of the Colorado River (see **Mainstem Colorado River Monitoring**). We suggest that trammel nets are not appropriate for sampling in the LCR, but could be valuable for use in eddy fences in the mainstem where water temperatures are cooler.

2.2. The current biological opinion requires an annual update of the ASMR model of the adult humpback chub population. What is the most efficient way to monitor to achieve this annual update?

- Current empirical monitoring programs provide relatively rapid annual updating of stock status, so should provide an early indication of stock status and trends (the periodicity of reports suggests that annual updates are obtainable at present levels of effort).
- Standardized reporting of field programs should be implemented so that results can be compared and time series for all programs are readily available.
- The species is so long lived that annual abundance estimates of the adult population are not needed or warranted.
- Annual updates of field sampling data are easier and cheaper than ASMR model updates, so should be considered as a replacement for annual updates

of the ASMR model. For instance, recruitment can be monitored with empirical catch per unit effort of fish shorter than 150 mm TL.
- The intensity of sampling effort required for annual updating of the ASMR model would require increased support for the ASMR model, perhaps by hiring a position to maintain the model.
- Even though BO calls for ASMR to be updated annually, the panel recommends a 3–5 year reporting cycle instead.

2.3. Does the panel agree that parasite monitoring be conducted every 5–6 years as recommended? If not, what alternative monitoring schedule is recommended? How should parasite monitoring data be used?

- The rationale for parasite monitoring on any temporal scale relative to management objectives is not clear and use of results from a parasite monitoring program is difficult to assess. Therefore, a time scale for sampling is difficult to recommend.
- If lethal monitoring is conducted, other tissues should be saved for analysis, especially otoliths, fin rays and other structures for age estimation and possibly soft tissues for genetic analysis.
- If water temperatures rise, more intensive surveys may be needed, but these may be non-lethal sampling methods. External parasites should be monitored opportunistically, in conjunction with other monitoring.

2.4. Can the panel recommend a range of stock assessment options at differing levels of effort and expense so that managers can evaluate the relative range of information to be gained from a range of expenditures? In other words, what are the most precise, most expensive stock assessment methods, and what are the less precise, less expensive methods?

- Current levels of field sampling include large-hoop netting by AZFG in the lower 1,200 meters of the LCR since 1987 (20–30 days each spring) and four small-hoop netting trips by USFWS in the lower 14 km of the LCR since 2000 (2 spring and 2 fall sampling events). These field programs are supported by extensive analytical work on the tag database.
- Evaluation of HBC programs would benefit from development of an assessment framework that lays out how the information being collected in the various monitoring programs is used for assessment of population status. The framework can be used for annual or semi-annual updates. Further, implications of adding, removing or modifying programs on program capability can then easily be evaluated.
- Both hoop netting surveys may provide similar indices of stock status and trends, but comparison of the two surveys has not been attempted and differing formats of data provided in reports by each agency hinder direct comparison. Therefore, the 2 hoop netting surveys should be compared to determine if sampling effort can be reduced or consolidated to provide more concise assessment of stock status and trends.

- The ASMR model requires data from field sampling programs and is an small incremental cost to field programs. The ASMR analysts should consider their minimum tagging requirements as a lower benchmark of effort for programs tagging HBC.

2.5. Does the panel have any concern over the amount of handling (monitoring) of humpback chub that is currently conducted? Is too much monitoring being conducted now? If so, what handling should be curtailed or eliminated to reduce this concern?

- Monitoring of humpback chub subjects 65–80% of all fish in the population to handling at current rates of PIT tagging and sampling, although the frequency at which individual fish may be handled, especially during spawning season, was not clear.
- Despite this level of handling, the population has been increasing since 2000, which suggests that handling stress is not causing a decline in the population. However, population recovery may have been slowed by handling mortality.
- Handling protocols have been developed for the Colorado River Basin, especially for bonytail chub. Therefore, written protocols for the Colorado River humpback chub monitoring may be desirable. A HBC PIT tagging protocol has been established.
- Overall, the panel feels that PIT tagging mortality for adult fish is probably low and is pleased that crews tagging in the field in AZ are trained in tagging protocols.
- Tagging mortality should be assessed, especially for small fish. This could be accomplished in live cages during annual PIT tagging. . Fish held in the LCR should probably not be held longer than 24 hours, and perhaps less than 12 hours.
- Recent studies with Pacific salmon have found that tag expulsion rates of 18% occur when small fish are tagged and are at liberty for several years. PIT tagging was also found to cause a 10% increase in long-term mortality. This highlights the potential risks of PIT tagging small HBC.
- A programmatic goal should be established to reduce handling of any endangered species. The Panel views the PIT tag antenna array as a potentially useful tool to meet this goal. The intensity of sampling and tagging in the LCR should be evaluated to determine minimum requirements to meet assessment and surveillance needs.

4. Mainstem Colorado River Monitoring Program

CMINS for mainstem fish populations are to "determine and track abundance (or recruitment) and distribution…." for native and non-native predatory fishes. From a practical perspective, tracking *relative* abundance is more likely to be used as a management tool because estimating absolute abundance is daunting in such a large environment.

The anchor of the mainstem sampling program is a boat electrofishing survey that has been conducted annually for the past 10 years. While originally directed at trout species, this program is also suited to indexing carp and sucker relative abundance. The program has established a rigorous objective of CV = 10% for annual CPUE estimates for the whole system and in some years nearly 1300 individual samples (i.e. electrofishing runs) have been taken. The panel questioned whether this level of precision was needed for management that seems to rely on tracking trends rather than estimates of absolute abundance. The informative power analyses conducted by AZGF suggest that a large reduction in effort would have only small impact on CV and perhaps a target CV of 15% for rainbow trout would still yield adequate information for all species sampled by the gear.

Over the years, various hoop and trammel net surveys have been conducted to sample fish not vulnerable to electrofishing surveys, and in particular HBC. Much has been learned about sampling and recent results were nicely summarized by Ackerman (2008), which suggests that a tighter link between management objectives and sampling protocols is needed. Currently, a clearly defined assessment procedure is needed for developing annual monitoring data into a format or time series for identifying status relative to management objectives. For example, a mark-recapture estimate for HBC in the LCR reach of the mainstem was attempted in 2005, but the purpose of the estimate in the overall assessment of HBC status was not clear. By modifying the sampling protocol for this one-time estimate, results from the 2005 survey for HBC were rendered incomparable to other years of sampling. As noted by the 2001 PEP, maintaining a continuous, comparable series of data is paramount in a successful monitoring program.

The sparseness of aggregations of HBC in the mainstem represents a significant challenge for monitoring. The Panel suggests that GCMRC carefully consider its objectives and information needs when developing a sampling protocol for these fish. If the objective is to track relative abundance of these fish, which are largely older aged individuals, periodic sampling (every 2–3 years) focused on selected locations using trammel nets may be adequate. Conversely, if the focus is on reproduction and recruitment within aggregations, annual larval or juvenile sampling may be required, perhaps coupled with less frequent adult sampling.

Monitoring invasions and trends of potentially harmful non-native species was identified as an information need. Detecting invasions and tracking relatively scarce species is challenging in a large environment. In other systems, available information on habitat requirements and vectors for potential invaders are used to identify sampling locations most likely to harbor invaders (Campbell et al. 2007; Lee et al. 2008) and speaks to the relative merits of randomized versus informed sampling. In 2001, the PEP identified a need for risk analysis of potential invaders to establish their relative risk to native fish, and the current Panel understands that such an analysis is underway, along with an analysis of environmental requirements, points of introduction and habitat use. This work should provide information to rank species (and habitats or locations) for sampling.

Recommendations

1. Monitoring trends in relatively abundant species throughout the mainstem, and also detecting the occurrence of rare species, would be best served by a two-pronged approach. The current stratified random electrofishing survey should be continued to provide information on trends and distribution of relatively abundant native and non-native species. However, effort could likely be reduced with little loss of information. This extensive approach needs to be complemented by a second strategy intended to detect rare species, such as more intensive sampling using a variety of passive and active gears at a smaller number of fixed surveillance locations where potentially detrimental non-native species are most likely to be found. This sampling component can also include locations where more detailed information on native species is warranted (e.g., known HBC aggregations). Together, these two sampling strategies address a range of monitoring goals, each to varying degrees (Table 1), and in combination address many of the questions posed by the TWG.

2. Evaluate impacts of reducing river-wide electrofishing from 2 trips to 1 trip per year. The primary goal of the stratified random electrofishing survey is to track general changes in distribution and relative abundance of trout populations and other species captured by this gear. A single trip currently yields 350–450 samples along 360 km of river, which is a relatively high rate of sampling. An annual CV (for trout at least) of 10% is probably more precise than is really needed, especially for longer-lived species that are unlikely to change in abundance significantly year to year. Existing data could be used to evaluate loss of precision in relation to reduction in sampling intensity.

3. Add a targeted sampling program at likely locations for non-native species colonization (e.g. above Lake Mead, below Lake Powell, and stream mouths, springs, below large rapids). This program would deploy a suite of sampling gears, such as trammel nets, hoop nets, minnow traps, angling, set-lining, seining, and back-pack electrofishing (these sites could also be sampled by boat electrofishing during the stratified random electrofishing survey trip). The primary objective is to detect colonization by non-native species and changes in their distribution in the mainstem that would not be detected in the stratified random electrofishing survey. The proposed risk assessment for invasive species could be used to determine the locations, habitats, gear types, and periodicity that would be most effective.

4. Designing a monitoring program for non-LCR HBC remains challenging, but should be based on refined management objectives and CMINs that clarify information needs. For example, if the focus is on status of a few aggregations

outside of the LCR region, a focused sampling regime to assess abundance and recruitment may be appropriate. This program could be tied (or alternated) with targeted mainstem sampling. Given the extensive experience with trammel and hoop net sampling from earlier surveys, determining if the information generated by a proposed sampling regime will satisfy the information needs should be possible.

5. Alternative means of sampling should continue to be pursued to identify the most efficient means to detect new species and changes to the distribution and abundance of existing species.

Responses to Questions: Mainstem Colorado River Monitoring

3.1. Given the distribution of humpback chub in Grand Canyon, how should monitoring efforts for this species be distributed?

- The current tag-ASMR program adequately assesses abundance of the LCR and LCR inflow aggregations of HBC, which is the largest component of the population and thereby drives overall trends.
- Current monitoring programs enable indexing status and trends of HBC throughout the Grand Canyon by:
  - Electrofishing at 11 sampling reaches during 2000–Present to monitor native and non-native species distribution and population density.
  - Trammel netting for adult native species and hoop netting for juvenile native species in 11 sampling reaches was conducted during 2002–2006 but was discontinued because of concerns about post-handling mortality on humpback chub (particularly in trammel nets).
    - However, recent laboratory studies suggest that trammel netting induces little mortality on a related species at temperatures occurring in the mainstem Colorado River.
    - Therefore, trammel netting can be safely added back into sampling design without risking significant incidental mortality of native species.
- Sampling design is based on random selection within reaches, which is useful for identifying a major change in distribution or development of a new aggregation, but is not likely to be efficient at monitoring known sites where humpback chub are likely to occur.
- If a program goal is to monitor specific aggregations of HBC in the mainstem, then a fixed sampling design will be needed for these areas and translocation sites.
- Sufficient data likely exist to determine the relation between sampling intensity and precision to evaluate what can be accomplished with a mainstem aggregation monitoring program.

3.2. Given that various levels of monitoring effort are required to assess various levels of fish population changes, and unlimited funding is not available, can the panel recommend one or more processes for determining how to allocate limited resources to native and nonnative fish monitoring?

- Monitoring programs in the LCR and mainstem are mature enough that some thought should be given to how the information from the programs will be used for reporting or decision-making. An assessment or reporting framework for each component of the program should be developed to clearly show how results of monitoring activities contribute to evaluation of status and trends. This type of process would then permit an assessment of the implications of modification to delivery of status and trend information.
- The current sampling design includes only one active capture method (electrofishing surveys), so should be enhanced by adding passive capture methods, such as trammel and hoop nets, that are known to be effective for sampling native species with little post-handling mortality at temperatures that are likely to occur in the mainstem Colorado River.
- The current sampling design is stratified to encompass 11 reaches within the Colorado River between Lake Powell and Lake Mead, so provides an excellent design for assessing status and trends of relatively abundant native and non-native species throughout the river.
    - However, the design should be modified by adding known points of likely invasion of non-native species based on a risk analysis of species colonization (e.g. tributaries).
    - Similarly, the design should be modified by adding known points of likely populations for native species (e.g. translocation areas and tributaries).
    - These sampling sites for non-native species invasions and native species recovery should be the focus of targeted surveillance sampling (see below).

3.3. Considering the trade-offs between monitoring cost and sampling precision, are there any suggested spatial sampling designs (systematic, random, stratified) that optimize the sampling distribution (e.g., use a multi-level approach that integrates a priori the sampling efforts among existing research and monitoring programs that are presently conducted independently)?

- As stated in response to question #2, available data from trammel netting and electrofishing surveys can be examined when designing a hybrid sampling program.
    - Systematic sampling at fixed index locations should focus on detecting invasions by non-native species and recovery of native species at known aggregations and translocation sites.
    - Random sampling at stratified-random locations should focus on status and trends of both non-native and native species throughout the Colorado River.
- Staff within the GCMRC has the expertise to design a hybrid sampling program that optimizes across objectives (see 4.1-2).

- Models that employ simulated sampling to test different sampling schemes could be useful for determining how to best allocate sampling effort (e.g., whether to sample a few sites many times or many sites a few times).

3.4. How should the monitoring program allocate sampling effort in the monitoring design that temporally accounts for sampling constraints (e.g., NPS non-motor season) or seasonal differences (e.g., developmental and dispersal histories)?

- Current mainstem sampling protocol for electrofishing likely over-samples at 2 trips per year, so can likely be reduced to an annual trip. A target CV of 20% rather than 10% is an appropriate level of precision for annual CPUE estimates.
- Surveillance monitoring of status and trends can likely be set at a single point within the year, so periodic or seasonal sampling within years is not likely needed. This sampling can be scheduled during the motor season to facilitate logistics.
- Allocation of sampling effort within years is estimable by analysis of existing data from surveys that are conducted multiple times each year.
- Effort saved by reducing the electrofishing survey protocol can be reallocated for monitoring colonization by non-native species and recovery of native species at fixed sites (see above).
- Monitoring at fixed sites in the mainstem should be scheduled during the motor season because rapid movement among sites will be necessary.

3.5. Should routine monitoring methods be altered to allow detection of nonnative fish invasions and expansions? If so, how? If not, what sampling program should be instituted to allow detection of new invasions or significant expansions?

- See responses to questions #1–4.
- A mixed sampling design of stratified-random and fixed-index sampling locations is needed for monitoring both status and trends of established populations and detecting fish invasions and small populations of recovering native species.
- Local knowledge should be employed to identify "hotspots" such as creek mouths, or below large rapids for surveillance of new species or changes in distribution of existing species.

3.6. Given that the primary focus of many GCDAMP management actions is to improve spawning and rearing conditions for native fish in the Colorado River, what metrics should be evaluated for assessing these actions (survival, growth, abundance, distribution) and what are promising sampling designs?

- Spawning and initial rearing success are measured most directly through sampling of native species at an early life age or stage, such as yolk-sac larvae, as is presently done elsewhere in the basin for razorback sucker and bonytail chub.
- Early life-stage sampling is part of the nearshore ecology project, which will help to frame future monitoring needs and methods for the mainstem.

- Detecting recruitment of native species requires a sampling method, such as electrofishing or hoop netting, to which pre-recruit age classes of native species are vulnerable to capture.
- Detecting recruitment of native species also requires sampling where populations are being established, such as through translocations.
- Successful spawning and production of early life stages can be indexed by age-0 catch rate in an appropriate sampling gear in an appropriate location (e.g. seining in backwaters).
- Alternatively, the ultimate success of management actions can be measured by monitoring adult abundance at locations for population recovery (see above).

3.7. How can monitoring of the humpback chub mainstem aggregations best be conducted to determine if humpback chub are spawning in these locations?
- See response to questions #1 and #6.
- Sampling for larval or juvenile life stages of HBC directly indexes successful spawning and rearing of mainstem populations. However, determination of recruitment success is probably more important than spawning alone.
- Alternatively, telemetry can be used to determine if adult fish aggregate for spawning (assuming the species aggregate for spawning, which is not known at present).
- For some species, a predictable cycle of hormones precedes reproduction, so small blood samples can be used to evaluate maturation of these aggregations.

3.8. Should GCMRC and cooperators establish separate monitoring for natives and nonnatives, or can the CMINs be addressed if these efforts are conducted together?
- See responses to questions #1–4.
- Established populations of native and non-native species can be monitored for status and trends by the current stratified-random electrofishing sampling design (and perhaps enhanced by judicious use of trammel and hoop nets; see 3.2).
- Colonization of non-native species and recovery of native species can be monitored for detection by the proposed surveillance sampling design (mixed gears; see below).
- In late summer or autumn, many species are active, so are vulnerable to capture in passive gears that are proposed for use in the targeted sampling design.

3.9. Are there multiple sampling methods and gear types (nets, traps, electrofishing, hydro-acoustics) that could be used in combination (temporally/spatially) that would best inform the monitoring objectives?
- See responses to questions #1–4.

3.10. When allocating sampling effort, should river segments or habitat features be used to stratify the sampling distribution? And if so, should the number of sample units be selected based on the proportion of available strata or evenly distributed among strata?

- The current strategy for stratifying sampling effort (which is based on river segments) is appropriate for monitoring status and trends of relatively abundant species, but is not likely appropriate for detecting invasions by non-native species or recovery of rare native species.
- For surveillance of non-native species colonization, other information about where these species might occur should be used to inform the selection of sites (e.g., through a risk analysis).
- In addition, analysis of existing capture data may be useful to devise habitat associations, from which samples could be drawn.
- Adaptive sampling for non-native fish in target areas may also be useful for detecting new non-native species or small populations of native species.

Non-Native Fish Downstream Monitoring Program

4.1. Is the current sampling design sufficiently robust enough both spatially and temporally to monitor a change in status and trends in the distribution, composition, and abundance of nonnative fish species?

- The current design is adequate for monitoring status and trends of established populations of native and nonnative fish species, but not for rare species. Further, the prescribed level of precision (CV $\leq$ 10%) is likely more restrictive than needed for detecting realistic changes in relative abundance, especially if surveys are conducted annually.
- The current design should be modified to include surveillance monitoring at likely locations for non-native species colonization and recovery of native species (see above).
- Analysis of the relation between the number of species captured and sampling effort may be helpful in allocating overall effort and choosing among gear types.

4.2. Would using alternate sampling methods or gear types in addition to electrofishing provide greater insight on fish distribution, composition, and abundance?

- Yes. Many species known to be present in the watershed are vulnerable to electrofishing, so will likely be detected (e.g. Centrarchids and Percids). However, some species known to be present in the watershed are less vulnerable to electrofishing, so would not be as easily detected (e.g. Ictalurids).
- The mainstem electrofishing survey should continue with surveillance forays at prime locations for non-native species colonization (e.g. carp pond at Lee's Ferry; upstream and downstream reservoirs, and tributary streams).
- A second survey using a mix of passive and active capture methods other than boat electrofishing (e.g., trammel nets, hoop nets, hooks, and backpack, barge or prepositioned electrofishing) should focus on prime locations for non-native species colonization. The likelihood of detecting rare species increases with repeated samples using multiple gears.

4.3. Should electrofishing effort be quantified by time and/or distance?

- Electrofishing effort can be quantified by either time or distance and is commonly standardized to both metrics of sampling effort.
- Existing survey data can be explored to understand how time and distance relate to one another as measures of sampling effort, but both should be recorded and used as appropriate.

4.4. Should sampling areas be stratified by geomorphic reaches? Or should another type of strata be used in the sampling design?

- Stratified-random sampling design for mainstem electrofishing survey is correct for monitoring of existing, widespread, populations (i.e., stratification by geomorphic reaches is appropriate).
- However, sampling for monitoring colonization by non-native species should not be randomized, but rather, should be focused in areas where non-native species are likely to be introduced (tributary streams) or in habitats where they are more likely to be found.
- Likely sources for non-native species introductions are already known, so should be added to the mainstem monitoring program (see above).

4.5. Would other types of abundance indices (e.g., occupancy rate) be more appropriate for monitoring than conventional catch rate indices?

- Occupancy rate is the fraction of sites visited in a year at which a particular species is captured (detected) in a year.
- This typically requires much more sampling than is presently invested in monitoring, so does not represent a reasonable alternative to catch rate from current sampling, although models that allow for multiple years of sampling should be investigated.
- Detection probability is the likelihood that a particular species will be captured (detected) during a visit to a particular site. Baseline values can be calculated during multiple pass removal or mark-recapture studies.
- If past and future sampling can be used to derive relationships between detection probability and the density of various target species, then confidence values can be derived for the likelihood that a species is indeed absent from a location after repeated samples of non-detection.

4.6. Is the sampling coverage sufficiently representative of this system?

- Sampling effort is allocated throughout the river between Lake Powell and Lake Mead, so seems to be representative of the entire river system for widely distributed species, but probably not for rarer species. Small populations will not likely be detected by the current stratified-random design, so should be monitored using targeted sampling at likely points of colonization.
- Existing data can be explored to determine if reduced sampling intensity in the stratified-random survey would produce similar estimates of species status and trends (accuracy and precision).

4.7. Can native and non-native fish be concurrently monitored to detect changes in distribution, composition, and abundance?

- Yes. See responses to earlier questions related to mainstem and non-native monitoring.

4.8. What is the best monitoring design to detect newly invading, rare, or evasive non-natives?

- See responses to earlier questions related to mainstem and non-native monitoring.

Table 1. Degree to which various sampling efforts inform program monitoring goals

	System-wide trends in established species (RBT, BRT, Carp, HBC, FMS, BHS, others)	Detection of rare/new species (non-natives and natives)	HBC juvenile abundance and size at aggregations	HBC adult abundance and size at aggregations (and movement)	Size, abundance and movement of natives at the LCR confluence
Mainstem-wide stratified-random EF sampling	High	Low	Low or n/a??	Low or n/a?? (except for possible movement)	n/a
Mainstem fixed-site EF sampling (HBC aggregations)	Low	Med.	High	High	n/a
Mainstem fixed-site EF sampling (potential non-native sentinel locations/hotspots)	Low	High	n/a	n/a (except for possible movement)	n/a (except for possible movement)
Mainstem-wide multi-gear fixed-site sampling (HBC aggregations)	Low	Med.	High	High	n/a (except for possible movement)
Mainstem-wide multi-gear fixed-site sampling (potential non-native sentinel hotspots)	Low	High	n/a	n/a (except for possible movement)	n/a (except for possible movement)
LCR confluence reach predator-removal EF	n/a (low?)	Med.	n/a	n/a (except for possible movement)	n/a (except for possible movement)
LCR confluence reach hoop netting	Low	Low	n/a	n/a (except for possible movement)	High

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Appendix 2, PEP Briefing Document

LEES FERRY TROUT MONITORING PROGRAM

Background

In 1991, a trout monitoring program for the sport fishery in the 25 km long Lees Ferry reach was established and sampled quarterly at 15 fixed sites (550-1200 m) distributed downstream from Glen Canyon Dam to Lees Ferry. In 1996, modifications were made that reduced the frequency and number of fixed sampling sites (9 fixed sites). Each of the sites had been continuously sampled for over a 10-year period and was valued for seasonal and inter-annual comparisons. In 2000, a Lees Ferry Protocol Evaluation Panel (PEP) was convened to evaluate the current monitoring program. Panel recommendations included increasing the number of sites, reducing the size of sites, randomizing the selection of sampling sites, subdividing sites by habitat type (i.e., consistent with habitat designation used in Grand Canyon), greater emphasis on young of year, and implementing an alternate sampling method to account for under-sampling due to gear type biases with the conventional electrofishing method. In 2001, a solicitation and supplement was released that specified the sampling protocols to use for monitoring the Glen Canyon Lees Ferry Trout Fishery. The current monitoring program (2001-2009) uses a stratified random and fixed sampling design for site selection. Sampling frequency has varied between three and four times a year. A total of 36 sample sites are sampled each sample period; 9 fixed sites (historical) and 27 randomly selected sites. Annually, randomly selected sites are stratified without replacement based on habitat proportions (cobble bar, 9.2%; cliff, 15.4%; alluvial terrace/sand bar, 34.4%; and talus, 37.7%. In total, approximately 32% of the total shoreline in the Lees Ferry/Glen Canyon section will be annually sampled by combining both fixed and random sampling sites.

Management Objectives and Core Monitoring Information Needs

The following tables contain the management objectives (MO) and associated core monitoring information needs (CMIN) for Lees Ferry trout as specified by the Program stakeholders. **The goal of the protocol evaluation panel (PEP) is to provide GCMRC with a critical review and guidance on the conduct of a fish monitoring program to address the CMINs listed below.**

Table 1. Management Objective Related to Lees Ferry Rainbow Trout

MO #	Objective
4.1	Maintain or attain rainbow trout abundance, proportional stock density, length at age, condition, spawning habitat, natural recruitment and prevent or control whirling disease and other parasitic infections.
4.2	Limit Lees Ferry rainbow trout distribution below the Paria River of the Colorado River ecosystem to reduce competition or predation on downstream native fish

Table 2. Core Monitoring Information Needs Related to Management Objectives 4.

CMIN	Objective
4.1.1	Determine annual population estimates for age II+ rainbow trout in the Lees Ferry reach
4.1.2	Determine annual proportional stock density of rainbow trout in the Lees Ferry reach
4.1.3	Determine annual rainbow trout growth rate in the Lees Ferry reach
4.1.4	Determine annual standard condition (K_n) and relative weight of rainbow trout in the Lees Ferry reach
4.1.5	Determine if whirling disease is present in the Lees Ferry reach. Determine annual incidence and relative infestation of trout nematodes in rainbow trout in the Lees Ferry reach
4.1.6	Determine quantity and quality of spawning habitat for rainbow trout in the Lees Ferry reach as measured at 5-year intervals
4.1.7	Determine annual percentage of naturally recruited rainbow trout in the Lees Ferry reach
4.2.1	Determine and track the abundance and distribution of nonnative predatory fish species in the Colorado River ecosystem and their impacts on native fish.

Monitoring Questions

1. Are the current monitoring methods providing the information that managers need to manage the fishery, or should different metrics be pursued?
2. Is the current sampling design sufficiently robust enough both spatially and temporally to monitor a change in status and trends in the distribution, condition, and abundance of rainbow trout?
3. Are standard measures of relative abundance, e.g., catch rate, suitable surrogates for calculating absolute annual abundance? What are the relative risks of using CPUE instead of determining annual abundance? Does the PEP panel recommend that absolute annual abundance is needed for managers to make management decisions?
4. Should a greater emphasis be placed on young-of-year rainbow trout survival, growth and recruitment in this monitoring program?
5. Is the frequency of Lees Ferry rainbow trout population monitoring suitable for addressing the CMINs?
6. What is the best way to monitor downstream movement and fate of rainbow trout? What is the best way to determine if downstream movement is density dependent, or dependent on some other factor?

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Native Fish Monitoring Program

Native fish populations in Grand Canyon are key resources of concern influencing decisions on both the operation of Glen Canyon Dam (GCD) and other non-flow actions. To inform these decisions, it is imperative that accurate and timely information on the status of native fish populations, particularly the endangered humpback chub *Gila cypha* (HBC), be available to managers. Status and trends information on other native species and nonnative species are also important for managers. The assessments generated from monitoring programs are used, in part, to evaluate the effects of experimental actions, many of which are carried out under the auspices of the Glen Canyon Dam Adaptive Management Program (Program). The USGS Grand Canyon Monitoring and Research Center (GCMRC) is the primary science provider to the Program, in cooperation with U.S. Fish and Wildlife Service, Arizona Game and Fish Department, and National Park Service. This information is therefore crucial to (1) inform the program as to attainment of identified goals, (2) provide baseline status and trend information to be used as a backdrop to further understand mechanisms controlling native fish population dynamics, and (3) evaluate the efficacy of particular management policies in attaining program goals. Finally, results from this project are potentially useful in assessing changes to Federal Endangered Species Act listing status of HBC in the Colorado River.

Management Objectives and Core Monitoring Information Needs

The following tables contain the management objectives (MO) and associated core monitoring information needs (CMIN) for native fish as specified by the Program stakeholders. **The goal of the protocol evaluation panel (PEP) is to provide GCMRC with a critical review and guidance on the conduct of a fish monitoring program to address the CMINs listed below.**

Table 3. Native Fish Management Objectives

M.O. #	Objective
2.1	Maintain or attain humpback chub abundance and year-class strength in the Little Colorado River and other aggregations at appropriate target levels for viable populations and to remove jeopardy
2.2	Sustain or establish viable humpback chub spawning aggregations outside of the Little Colorado River ecosystem below Glen Canyon Dam to remove jeopardy
2.3	Monitor humpback chub and other native fish condition and disease/parasite numbers in Little Colorado River and other aggregations at an appropriate target level for viable populations and to remove jeopardy
2.4	Reduce native fish mortality due to nonnative fish predation/competition as a percentage of overall mortality in the Little Colorado River and mainstem to increase native fish recruitment
2.5	Attain razorback sucker abundance and critical habitat condition sufficient to remove jeopardy as feasible and advisable in the Colorado River ecosystem below Glen Canyon Dam

2.6	Maintain flannelmouth sucker, bluehead sucker, and speckled dace abundance and distribution in the Colorado River ecosystem below Glen Canyon Dam for viable populations

Table 4. Revised Science Planning Group (SPG) Core Monitoring Information Needs. SPG ranking where 1) is considered most important.

REVISED CMINs (SPG 2005)
1) CMIN 2.1.2 Determine and track recruitment (identify life stage), abundance and distribution of HBC in the Little Colorado River (LCR).
2) CMIN 2.1.2 Determine and track recruitment (identify life stage), abundance and distribution of HBC in the mainstem.
3) CMIN 2.3.1 Determine and track the parasite loads on HBC and other native fish found in the LCR and in the Colorado River ecosystem.
4) CMIN 2.4.1 Determine and track the abundance and distribution of nonnative predatory fish species in the Colorado River.
5) CMIN 2.6.1 Determine and track the abundance and distribution of flannelmouth sucker, bluehead sucker, and speckled dace populations in the Colorado River ecosystem.

Little Colorado River Monitoring

The humpback chub is the primary focus of native fish monitoring in Grand Canyon. The humpback chub population in Grand Canyon is centered near the confluence of the Colorado and Little Colorado rivers (LCR) in Grand Canyon. Valdez and Ryel (1995) describe the humpback chub distribution as consisting of nine aggregations throughout Marble and Grand canyons. However, the aggregation near the confluence of the LCR and Colorado River (hereafter referred to as the LCR population) is known to successfully reproduce. In recent years, most monitoring efforts have focused on the LCR population since it is the most numerous (~7500 adults compared to less than 500 in the rest of the aggregations combined) and the only documented source aggregation in Grand Canyon. Owing to logistical concerns and sampling efficacy, most effort to monitor this population is concentrated within the LCR even though this population resides both in the LCR and the mainstem Colorado River near the confluence.

Abundance and recruitment trends of the LCR population of HBC are assessed via catch-rate and open and closed population abundance estimators. In particular, we rely heavily on age-structured mark-recapture models (ASMR) to determine trends in HBC abundance and recruitment. Capture-recapture data collected in the system since 1989 support the annual stock assessment conducted with the Age-Structured Mark-Recapture (ASMR) model. Additionally, annual capture-recapture data are used to inform closed population abundance estimators. The primary data used to populate these models are collected during spring and fall and described below.

Annual Spring (March and April) Humpback Chub Data Collection in the Little Colorado River

In the spring two mark-recapture trips (12-day) are conducted annually in the lower 13.57 river kilometers (rkm) of the LCR to estimate the abundance of HBC > 150 mm TL. This program has been ongoing since 2000 and annually produces assessments of the abundance of HBC using closed population models. These efforts rely on multiple event mark-recapture analysis of Passive Integrated Transponder (PIT; Biomark, Inc.) tag data to produce abundance estimates using closed population models. Additionally, this sampling effort provides both data for populating the ASMR model as well as measures of relative abundance on the spawning and resident populations of HBC in the LCR below Chute Falls. Unbaited hoop nets (50-60 cm in diameter, 100 cm long, a single 10 cm throat, and covered with 6 mm nylon mesh netting) were the sole fishing gear used in this study. During both monitoring trips, each reach was sampled with 20 nets for the first ~24 h haul, then re-sampled by redeploying nets, often to new locations within the same reach. Evaluation of relative trends of other fishes, especially native bluehead suckers *Catostomus discolbolus* and flannelmouth suckers *Catostomus latipinnis*, is a desirable side benefit of this sampling. Some nonnative species, often ictalurids, are also captured with these methods.

Annual Fall (September and October) Humpback Chub Abundance Assessments in the Lower 15 km of the Little Colorado River

The fall sampling is aimed primarily at providing an estimate of the abundance of subadult HBC rearing in the LCR. These data support the ASMR model to assess HBC population numbers. Two trips into the LCR are conducted to collect the data used to construct these estimates in the fall (September and October). Findings from the fall trip are used as a complimentary comparison to the spring abundance estimates. Sampling is predominantly conducted using hoop nets evenly distributed throughout the lower 15 km of the LCR. Other types of sampling gear are not used in the LCR because they have been shown to be less efficient at capturing HBC >150 mm total length in the LCR.

Annual Spring Relative Humpback Chub Abundance Assessment in the Lower 1,200 m of the Little Colorado River

This program was established by the Arizona Game and Fish Department (AZGFD) in 1987 and has operated continuously through 2009 with the exception of the years 2000–01. This program annually produces assessments of the relative abundance (catch rate) of all size classes of humpback chub, flannelmouth suckers, bluehead suckers, speckled dace *Rhinichthys osculus*, and a host of nonnative fishes in the lower 1,200 m of the LCR. Data are collected during a 30–40-day period in spring (April and May) using hoop nets set in standardized locations distributed throughout the reach. In general, this effort represents the longest and most consistent relative abundance dataset available to infer trends for the population of HBC in the LCR. Results provide an independent comparison to the mark-recapture-based assessments. The statistical power of this portion of the monitoring program has not yet been assessed, but statistically significant differences in relative abundance are apparent in current data.

Monitoring and Translocation Above Chute Falls

Beginning in 2003, juvenile humpback chub have been “translocated” within the LCR from near the confluence of the LCR and Colorado Rivers to a location approximately 16 km upstream in an attempt to increase juvenile survivorship. As part of the monitoring program, two separate trips are conducted in the summer above Chute Falls in the LCR to monitor translocated individuals and potential offspring. These trips occur during late May when the LCR discharge is at base flow to provide an annual abundance estimate of HBC within this region. In addition to the annual population estimates, these data can be incorporated into the ASMR model. Moreover, because we have and will continue to implant these fish with PIT tags, it is likely that some individuals will eventually be recaptured in the lower LCR corridor and/or Colorado River, which would increase our knowledge of migration patterns.

Baited hoop nets are fished in the LCR corridor above Chute Falls (13.6 rkm), which is the upstream extent of the current LCR monitoring. Approximately 50 hoop nets are fished throughout this upper reach from 13.6 rkm to 18.0 rkm, with the average spacing between nets approximately 100-150 m. The overall reach will be broken down into two sub-reaches and each sub-reach fished for 3 days. The upper reach designation will be from 18.0 to 15.0 rkm (undesignated point below Blue Spring to first travertine dam above Chute Falls). Currently 18 rkm is the highest point in which HBC have been located above Chute Falls. The lower subreach will extend from 15.0 to 13.6 rkm (first dam above Chute Falls to Lower Atomizer Falls where lower LCR monitoring begins).

Questions for the PEP

1. Are the current monitoring methods and analytical approach employed by GCMRC, AZGFD, USFWS, and other cooperators sufficient to address the CMINs? If not, how should the field and analytical methods be improved to better address the CMINs?
2. The current biological opinion requires an annual update of the ASMR model of the adult humpback chub population. What is the most efficient way to monitor to achieve this annual update?
3. Does the panel agree that parasite monitoring be conducted every 5-6 years as recommended? If not, what alternative monitoring schedule is recommended? How should parasite monitoring data be used?
4. Can the panel recommend a range of stock assessment options at differing levels of effort and expense so that managers can evaluate the relative range of information to be gained from a range of expenditures? In other words, what are the most precise, most expensive stock assessment methods, and what are the less precise, less expensive methods?
5. Does the panel have any concern over the amount of handling (monitoring) of humpback chub that is currently conducted? Is too much monitoring being conducted now? If so, what handling should curtailed or eliminated to reduce this concern?

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Mainstem Colorado River Monitoring

Finding the appropriate design for monitoring native fishes in the mainstem Colorado River has been one of the most difficult challenges for the Program and GCMRC. The debate has centered around systemic sampling according to an appropriate randomized design versus focused sampling on areas of known higher abundance of native fishes, primarily humpback chub. Systemic surveys using hoop and trammel nets typically yield low and highly variable catches with low power of change detection. Focused surveys around the areas of known HBC aggregations typically yield higher and less variable catches, but provide no information about abundance or distribution of fish in the majority of the Colorado River. As mentioned above, in recent years efforts have focused solely on the LCR Inflow reach.

Mainstem native fish monitoring has historically focused on hoop and trammel nets as an appropriate gear type for capturing juvenile and adult native fishes. This was predominantly due to the observation that adult humpback chub were more readily captured using trammel nets than electrofishing. However, since about 2002, systemic electrofishing sampling trips (see NONNATIVE FISH DOWNSTREAM MONITORING PROGRAM below) have indicated a large increase in the catch-rate of flannelmouth and bluehead suckers and we now believe that this may be an appropriate gear type for monitoring abundance of these species. Additionally, the slow electrofishing of shorelines (~10 seconds/meter, the "Korman Slow Shocking Method") also appears to be effective at sampling juvenile humpback chub. However, trammel netting still appears to be the most effective method for capturing adult humpback chub.

In addition to the issues above related to sampling design and gear for monitoring changes in the abundance and distribution of native fishes in the mainstem Colorado River, perhaps the most relevant and difficult monitoring problem is to determine survival rate of juvenile native fishes in the mainstem Colorado River. This is particularly important as many proposed or implemented experimental management actions are aimed at improving rearing conditions for native fishes in the mainstem Colorado River. This is the topic of a current research initiative termed "Nearshoreline Ecology" and PEP input on this topic would be particularly helpful.

Questions for the PEP

1. Given the distribution of humpback chub in Grand Canyon, how should monitoring efforts for this species be distributed?
2. Given that various levels of monitoring effort are required to assess various levels of fish population changes, and unlimited funding is not available, can the panel recommend one or more **processes** for determining how to allocate limited resources to native and nonnative fish monitoring?
3. Considering the trade-offs between monitoring cost and sampling precision, are there any suggested spatial sampling designs (systematic, random, stratified) that optimize the sampling distribution (e.g., use a multi-level approach that integrates *a priori* the sampling efforts among existing research and monitoring programs that are presently conducted independently)?
4. How should the monitoring program allocate sampling effort in the monitoring design that temporally accounts for sampling constraints (e.g., NPS non-motor season) or seasonal differences (e.g., developmental and dispersal histories)?
5. Should routine monitoring methods be altered to allow detection of nonnative fish invasions and expansions? If so, how? If not, what sampling program should be instituted to allow detection of new invasions or significant expansions?
6. Given that the primary focus of many GCDAMP management actions are to improve spawning and rearing conditions for native fish in the Colorado River, what metrics should be evaluated for assessing these actions (survival, growth, abundance, distribution) and what are promising sampling designs?
7. How can monitoring of the humpback chub mainstem aggregations best be conducted to determine if humpback chub are spawning in these locations?
8. Should GCRMC and cooperators establish separate monitoring for natives and nonnatives, or can the CMINs be addressed if these efforts are conducted together?

9. Are there multiple sampling methods and gear types (nets, traps, electrofishing, hydro-acoustics) that could be used in combination (temporally/spatially) that would best inform the monitoring objectives?
10. In allocating sampling effort, should river segments or habitat features be used to stratify the sampling distribution? And if so, should the number of sample units be selected based on the proportion of available strata or evenly distributed among strata?

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NONNATIVE FISH DOWNSTREAM MONITORING PROGRAM

Background

The current downstream non-native fish monitoring program (2 trips/yr) uses a stratified random sampling design, such that sampling areas are distributed evenly among 12 geomorphic reaches found in the Colorado River that extend from Lees Ferry to Lake Mead (360 km). A sub-reach is randomly selected and sampled within each of the geomorphic reaches in the spring and early summer. Two electrofishing boats per trip each sample nightly 11 shoreline sites sequentially along opposing shorelines. The first site is randomly selected; the remaining sites are then sampled in series and separated by time (300 sec). Average number of samples per trip is between 350 and 450. Electrofishing is the primary gear type used and is quite affective in capturing rainbow trout and flannelmouth suckers. Under the current sampling design, the power to detect a change in CPUE of 21% decrease and 26% increase over a five–year period using an estimated coefficient of variation (CV ≤ 0.10) is 0.80. Fishing effort does not relate catch to linear shoreline distance or delineate sampling sites by macro habitat features.

Questions for the PEP

1. Is the current sampling design sufficiently robust enough both spatially and temporally to monitor a change in status and trends in the distribution, composition, and abundance of nonnative fish species?
2. Would using alternate sampling methods or gear types in addition to electrofishing provide greater insight on fish distribution, composition, and abundance?
3. Should electrofishing effort be quantified by time and/or distance?
4. Should sampling areas be stratified by geomorphic reaches? Or should another type of strata be used in the sampling design?
5. Would other types of abunace indices (e.g., occupancy rate) be more appropriate for monitoring than conventional catch rate indices?
6. Is the sampling coverage sufficiently representative of this system?

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