GRAND CANYON MONITORING AND RESEARCH CENTER

Protocols Evaluation Program
(Lee's Ferry Trout PEP)

"Final Report of the Lee's Ferry Rainbow Trout Monitoring Peer Review Panel"

September 10, 2000

U.S. Geological Survey Field Center
Flagstaff, AZ

PROCEEDINGS OF THE EXTERNAL PEER REVIEW WORKSHOP ON LONG-TERM MONITORING OF THE RAINBOW TROUT FISHERY IN THE LEE'S FERRY-GLEN CANYON PORTION OF THE COLORADO RIVER ECOSYSTEM

WORKSHOP- DATES: **May 22-25, 2000**

MEETING LOCATION: **USGS Field Center, 2255 N. Gemini Dr., Flagstaff, AZ**

LEE'S FERRY TROUT MONITORING PROTOCOL EVALUATION PANEL:

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Research Interests: Ecology of benthic invertebrates, statistics, stream ecology, biomonitoring, introduced species, whirling disease in salmonids.

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Research Interests: Fish population dynamics, statistics, statistical meta-analysis, investigating uncertainty, life-cycle modeling of salmonids.

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Research Interests: Fish ecology, fish management, statistics, sociological issues in fish management, ecology of reservoir fish populations.

EXECUTIVE SUMMARY

Procedures: The Lee's Ferry Trout Protocols Evaluation Program panel was charged with the responsibility of evaluating the Grand Canyon Monitoring and Research Center's existing rainbow trout monitoring program, sampling methodologies, frequency, distribution, and statistical analyses, and their appropriateness to addressing monitoring objectives. The Trout PEP panel acted collectively to review and provide recommendations and guidelines for developing an effective monitoring program for the future. The panel performed its work using information provided by GCMRC through printed materials, oral presentations, and a field trip to the Lee's Ferry-Glen Canyon reach of the Colorado River. Arizona Game and Fish Department personnel took us up the river from Lee's Ferry by boat on 22 May 2000 for a demonstration of electroshocking techniques for assessing rainbow trout abundance and size distribution. A second trip on the river on 23 May provided opportunities to observe the Colorado River fish, habitats, and forage during daylight. Individual panel members chose sections to write of the draft "findings and recommendations" report prior to departing from Flagstaff. D. A. Culver assembled and edited the final report in consultation with the other panel members by email.

Programmatic Recommendations: While the Trout PEP was charged to assess current monitoring protocols of the rainbow trout population, it is clear to the panel that an integrated view of the river that includes both upstream and downstream areas as well as terrestrial habitats is required for adaptive management of its resources. The panel found that such an integrated research program would benefit the adaptive management of the Glen Canyon and Grand Canyon resources, and that the GCMRC should work to achieve this goal through providing leadership among stakeholders and researchers alike. The panel recommends that GCMRC develop an explicit set of ecologically-based Study Objectives, based on desires of stakeholders, that will drive all activities, including design of Requests for Proposals, and that the Arizona Game and Fish Department take an active role in communicating the process to stakeholders. Further, the GCMRC should work to promote communication and outreach of Grand Canyon research to stakeholders and the broader research community.

Trout Monitoring Protocol Recommendations: The specific sampling protocols could be improved by increasing the number of electroshocking sampling sites back to 15, while sampling at each site for a shorter period of time, and adopting a truly random sampling site selection approach. The current sampling protocol is biased against small rainbow trout and those fish living in the main channel and along steep canyon walls, and habitats that might be viewed as "poor" trout habitat. Because current sampling sites are not representative of all available habitats, electrofishing results cannot be extrapolated to provide an independent estimate of population size. Similarly, the rainbow trout's tendency to stay in one place violates an important assumption of the use of tagging studies to measure total population size, namely that tagged fish mix randomly with the total trout population. The panel feels that these problems can be addressed with small changes in operating procedures of the GCMRC and the contractors that monitor the trout. Creel sampling should be continued because it provides important information on the fishery from the perspective of the fishermen. Juvenile trout should be sampled using traps or other appropriate gear, since they will be affected first by changes in discharge. Whirling disease will profoundly affect the Lee's Ferry trout population should it become established, so monitoring for this disease should be initiated.

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1. INTRODUCTION

1.1 Background The Grand Canyon Monitoring and Research Center (GCMRC), a unit of the Biological Resources Division, United States Geological Survey, Department of the Interior, is charged with monitoring and carrying out research on the Colorado River corridor in the Glen and Grand Canyons in order to evaluate the effects of water releases from Glen Canyon Dam. GCMRC convened a Protocol Evaluation Panel (PEP) to evaluate the program to monitor the status and trends of a tailwater rainbow trout fishery of a 25 km reach of the Colorado River from Glen Canyon Dam to Lee's Ferry, AZ. The fishery is predominately for non-native rainbow trout and is influenced by the operations of Glen Canyon Dam, whose cold hypolimnetic releases (8^oC) maintain a relatively constant temperature in the reach year-round, enabling trout to thrive, but at the expense of native fish species that were adapted to a river that had immense seasonal variation in discharge and temperature. The Arizona Game and Fish Department (AGFD) currently monitors the fishery under contract to GCMRC.

1.2 Charge to the Trout Protocol Evaluation Panel GCMRC requested that the Lee's Ferry Trout PEP evaluate the existing monitoring program, sampling methodologies, frequency, distribution, and statistical analyses used, and their appropriateness to addressing monitoring objectives. The Trout PEP would then act collectively to review and provide recommendations and guidelines for developing an effective monitoring program for the future. This report is the result of our discussions

1.3 Procedures The Lee's Ferry Trout PEP performed its work using information provided by GCMRC through printed materials, oral presentations, and a field trip to the Lee's Ferry-Glen Canyon reach of the Colorado River. The 16 separate printed material items included 2 previous PEP reports on physical and terrestrial resources, research reports, requests for proposals, proposals, journal article reprints, and presentation overviews. These materials were either mailed ahead of time or were provided during our work in Flagstaff before and after the field trip to Glen Canyon. Oral presentations were made on 22 May and 24 May in Flagstaff, and at Glen Canyon on 23 May 2000. The field trip began on 22 May, when Arizona Game and Fish Department personnel took us up the river from Lee's Ferry on two boats for a demonstration of electroshocking techniques for assessing rainbow trout abundance and size distribution. Because the electroshocking survey was performed after dark (8-11 pm), a second trip on the river on 23 May provided opportunities to observe the Colorado River fish, habitats, and forage base all the way to Glen Canyon Dam, with observations of fish at warm springs (flannelmouth suckers), gravel spawning sites (flannelmouth suckers, rainbow trout), and in backwaters (carp, flannelmouth suckers). Rainbow trout were also observed throughout the trip. The committee began its deliberations in Flagstaff on the evening of 24 May, and completed the discussions and an outline of the draft report on 25 May 2000. Individual panel members chose sections to write of the draft "findings and recommendations" report prior to departing from Flagstaff. D. A. Culver assembled and edited the individual segments into the several drafts and the final report in consultation with the other panel members via email.

2. SPECIFIC FINDINGS AND RECOMENDATIONS

2.1 GCMRC should develop an explicit set of Study Objectives, based on desires of stakeholders, that will drive all activities

The Lee's Ferry Trout PEP reviewed the printed materials provided and integrated the comments of a series of oral presentations within the context provided by an on-site view of the Lee's Ferry Reach of the Colorado River. There, all of the components were in place, from the dam, the canyon, the water, the fish habitat, the forage base, and the fish, to the recreational fishermen, boaters, and hikers who were using the resources.

Based on this information, the PEP feels that a specific set of Study Objectives is needed for the monitoring program, developed in communication with stakeholders. GCMRC needs to specify explicit objectives associated with trout management, short-term decisions (e.g. access, limits on fish, boating activities, and manipulations of the discharge and habitats) associated with achieving these objectives. This recommendation is in agreement with deficiencies identified on other monitoring programs (Gold et al. 2000), specifically, 1) the lack of a conceptual model, and 2) weak linkages between monitoring and research programs, and 3) weak linkages to stakeholder objectives and information needs.

As will be seen in subsequent sections of this report, **we recommend that an ecological approach be used in developing the study objectives to meet stakeholder desires**. That is, GCMRC needs to specify objectives associated with understanding the ecosystem, which on the long term will assist with Adaptive Management. For example, it is evident that discharge water from Glen Canyon Dam is cold, low in algae, relatively high in nutrients, and the river thus behaves like a chemostat, generating gradients with time and distance downstream in planktonic algal abundance and temperature (increasing), and dissolved nutrients (decreasing). With exposure to light, plankton algae can reproduce rapidly, dividing up to once or twice a day, causing a gradual increase in plankton algae with distance down the reach. The concentration at any given location is thus a combination of the speed of the river and the dynamics of planktonic algal growth and consumption by herbivores. Attached algae, however, can be abundant throughout the reach, continuously bathed in cold, nutrient-rich water, with high light during the day. We can picture continued growth of *Cladophora* until filaments are so long they break off and drift downstream, perhaps accumulating in deep pools. Despite these strong gradients in plant productivity with distance downstream, the trout fishery is being monitored as a single, large population that mixes regularly. Tagging results, however, suggest that individual trout pretty much remain in one location, meaning that they are occupying one region of the gradient. Furthermore, we observed that the discontinuous distribution of gravel bars strongly affects the access of fishermen to the trout resource, further illustrating the importance of the location of individual trout on the gradient. Any change in discharge patterns from Glen Canyon Dam will clearly influence the dynamics of this system in a non-linear manner.

2.2 Leadership by the Arizona Game and Fish Department (AGFD) is needed to suggest to stakeholders what management options are and which are optimal.

AGFD has an important role in communicating the results of scientific studies associated with adaptive management, and in receiving and interpreting needs communicated by the public. It has opportunities to have direct contacts with the public through its standard communications about fish, wildlife, boating, and hunter education through published research reports, extensive websites, displays at boat shows, and the like. It also communicates with the public through its information programs associated with fishing license sales, and through creel surveys (discussed further below) and fishery regulation enforcement. AGFD automatically obtains credibility for its knowledge of the Colorado River fishery by its regulation-making authority. Thus, whether or not AGFD has the contract to monitor the trout in Lee's Ferry reach, it has the opportunity and obligation to communicate with the public about the management of the fishery there.

2.3 GCMRC should provide leadership and promote collaborative research that leads to integrative understanding of the Colorado River from Glen Canyon through the Grand Canyon.

2.3.1 The leadership role of the GCMRC

As clearly articulated by the National Research Council (1999), the Adaptive Management Program for the Glen Canyon and Grand Canyon Ecosystem is hampered by lack of a broad vision that results in management objectives that do not encompass the entire ecosystem. Although our task was to evaluate monitoring and research of the rainbow trout fishery in the Glen Canyon section, it became clear during our visit that the lack of vision affected all research and monitoring. The GCMRC should provide leadership in this regard and use its unique position to work with stakeholders to develop a consensus vision for the Glen Canyon and Grand Canyon Ecosystem that could then provide the basis for ecosystem-wide management objectives. One way the GCMRC could begin the process of taking a leadership role is by the addition to the staff of a senior scientist with broad ecosystem experience. This scientist would take the lead in bringing together GCMRC staff and stakeholders to 1) reach a consensus on the vision for the ecosystem, 2) define clear management objectives and resulting research objectives that encompass the whole ecosystem, and 3) develop a scientific basis for trade-off analysis between competing objectives (perhaps through research).

2.3.2 Collaborative work and integrated understanding will improve research and management effectiveness.

Understanding the operations of an ecosystem is a difficult and daunting task that requires research and monitoring by diverse groups to be collaborative, or at least coordinated. Moreover, the results of the research of these diverse groups must be integrated. It was clear during our visit that conclusions resulting from the research and monitoring of the rainbow trout fishery (and presumably other research areas) were limited by the lack of research coordination with other groups. Although the GCMRC provides peer review of the science its supports, the collaboration among diverse sciences (e.g., fishery biology & physical science) or among similar sciences (e.g., fishery biology & terrestrial ecology) required to understand an entire ecosystem appears to be absent. For example, the 1997 Strategic Plan includes four major research categories (physical, biological, cultural and socioeconomic). The biological category includes four resource areas (fishes, vegetation, wildlife habitat, endangered species). To understand the impact of dam manipulation on fishes, fishery biologists need to make connections with the physical resource group and other groups within the biological category (e.g., vegetation, native & endangered species). Currently, the rainbow trout research group appears to have little connection to researchers in other areas. This lack of coordination hampers research on rainbow trout by limiting collection of important, non-trout data that could impact the trout fishery. At the same time, uncoordinated collection of data by different groups often leads to a data set comprised of incompatible component parts, which are thus of reduced value.

2.3.3 The GCMRC and the new senior scientist should ensure that the research and monitoring it supports leads to an integrative understanding of the entire ecosystem.

We have several suggestions that might help in this regard. **First**, management objectives (see above) should be developed within the framework of the ecosystem as a whole. Research needs, identified as the result of examining current research in the light of these larger management objectives, should be integrated across categories (e.g., physical, biological) and clearly articulated in integrated research objectives. **Second**, Requests For Proposals (RFPs) should encourage and facilitate coordinated or collaborative research directly applicable to integrated research objectives. This would encourage collaboration among physical and cultural scientists and terrestrial and aquatic biologists. **Third**, the call for proposals should specify that proposals address the research objectives specified by the GCMRC and analyze samples and data relative to those research objectives. **Fourth**, we recommend that applicants provide short preproposals prior to submission of full proposals. Preproposals should be reviewed by a panel of scientists and graded for scientific merit, scientific coordination or collaboration and how well the research meets integrated research objectives. This would allow the GCMRC to request clarification in full proposals and to perhaps suggest research aspects that were not included in preproposals but were viewed as important to the panel or the GCMRC. **Fifth**, we recommend that GCMRC favor proposals that include matching funds, either direct or in kind, to leverage additional research results for available funds. Moreover, we feel that GCMRC should favor proposals that include undergraduate and graduate students involvement in the research, providing a pool of trained scientists for the future that is familiar with the unique characteristics of the impounded Colorado River.

2.3.4 The GCMRC should promote outreach involving Grand Canyon researchers and other members of the scientific community.

Such outreach will enhance scientific exchange, make the research accessible to the rest of the scientific community, spark interest in the available research opportunities and potentially increase collaboration by increasing the size of the pool of scientists participating in Grand

Canyon research. Below we have some specific suggestions to increase outreach. **First**, the GCMRC could organize symposia on Grand Canyon research results to be presented at existing national meetings (e.g., American Fisheries Society, Ecological Society of America). This would increase the profile of GCMRC-funded research, get feedback on research results from nonparticipating scientists and potentially interest other scientists in work on the Grand Canyon. **Second,** GCMRC could provide small grants and office or laboratory space to bring visiting scientists to their facilities. Visiting scientists could work with existing grantees to add important scientific expertise to projects. Alternatively, visiting scientists could propose pilot projects investigating novel research directions. Visiting scientists could also work with GCMRC staff and might be particularly helpful in suggesting various ways that research objectives and projects could be integrated.

2.4 Monitoring and research should be directed towards ecosystem understanding and should directly support management decisions.

The management decisions that will need to be made should motivate the research. This research can be composed of more applied work (such as monitoring) that will be used to make immediate decisions, as well as integrative work that will assist in decision-making in the long term.

As a first step, all potential management actions that may affect the trout population should be described:

- Changes in fishing regulations.
- Changes in dam discharge regime.
- Changes in the temperature of the dam discharge.
- etc…

The current understanding of the system can then be used to determine which type of data collection will most efficiently reduce uncertainty in prediction of the outcomes of different management actions. For example, one question might be: "How will increasing the take by a certain amount (the action) affect the size composition of the trout population (the outcome)?" Using the Walters-Speas model, it would probably become obvious that the answer to this question is very sensitive to the assumptions about density-dependent growth. In other words, a more precise understanding of density-dependent growth would substantially reduce the uncertainty in how the size composition would respond to increased take. Using estimated costs of different types of data collection one could then determine which type of data most efficiently reduces uncertainty in the density-dependent growth relationship, and therefore most effectively improves prediction of the outcome. For example, one might find that pit-tagging fish in certain size classes in conjunction with local experimental removals provides the most information.

The Walters-Speas model provides a useful tool for formally describing the current understanding of the Lee's Ferry rainbow trout population dynamics using biological knowledge and available monitoring data. More complex models (like the Grand Canyon Ecosystem Model) that include macrophytes, invertebrates, stream morphology, etc. can also be used to focus data collection to gain a better integrative understanding of the Lee's Ferry ecosystem.

As GCMRC moves forward from the initial model construction, we recommend the following:

- Provide a clear description of specific goals of the model. Specify what types of questions GCMRC will and will not be able to answer using the model results.
- Describe the different model components and their justification.
- Describe the different types of data used and how they drive the model results.
- Break down and describe the sources of uncertainty in the model:
    - Given the model formulation is approximately "correct", uncertainty can be calculated using techniques like likelihood profiling, or bootstrapping.
    - Uncertainty in the model form can be assessed by comparing the fit of alternative models, and determining how sensitive the predictions are to model choice (a sensitivity analysis).
- Use caution when relaying model results. Include results from the uncertainty analysis above, and clearly state the assumptions intrinsic in the model.

2.5 Linkages between upstream and downstream areas and between aquatic and terrestrial habitats must be explicitly acknowledged.

Streams and rivers are extremely "open" and "connected" systems and, as such, ecosystem dynamics in a specific river reach are strongly tied to physical and biological factors occurring both inside and outside the reach. Thus, understanding the biology of organisms (e.g., rainbow trout) within a reach requires information on how inputs from upstream and surrounding aquatic and terrestrial ecosystems influence the state of the ecosystem within the reach. The operation of the Glen Canyon dam, the main experimental factor, is the only external factor for which effects on downstream ecosystems are explicitly being explored. For example, dam operations have been correlated with rainbow trout and their food base in the Glen Canyon reach (McKinney et al. 1999a, b, c; McKinney and Persons 1999). However, since flow manipulations were, in the strict sense, essentially unreplicated and uncontrolled experiments, understanding the mechanisms affecting rainbow trout would make a more robust case that flow manipulations were the primary cause of any observed changes in the rainbow trout fishery. Relationships among dam release, the rainbow trout fishery, and other ecosystem components (e.g., macrophytes, phytoplankton, chemical water quality) should be made even more explicit by developing hypotheses and testable predictions regarding how flow modification affects the rainbow trout fishery and other components of the ecosystem, and the interactions and mechanisms producing these effects.

To study connections among the Glen Canyon ecosystem and its fishery with upstream and downstream aquatic ecosystems and surrounding terrestrial ecosystems, several types of questions need to be addressed. For example, How do changes in the Lake Powell ecosystem influence the downstream Glen Canyon ecosystem? Could any changes in the Lake Powell ecosystem that were coincident with flow modifications confound the interpretation that changing flow patterns were the force driving changes in the rainbow trout fishery? How do changes in discharge “cascade” through the system by influencing the Glen Canyon reach, which in turn influences the downstream Grand Canyon reach? Finally, what are the connections between the rainbow trout fishery and its ecosystem and the surrounding terrestrial system? For example, are high juvenile rainbow trout abundance and stable water levels responsible for the Great Blue Heron rookery? Such connections must be explicitly acknowledged and treated in order to understand the effects of flow modification the Glen Canyon ecosystem and its rainbow trout.

We believe that the time is right for those working on the rainbow trout fishery to begin to make these connections. We have some suggestions that might help to forge these links. **First**, because the biologists have gained much useful correlative information concerning the effects of dam operations on the rainbow trout fishery and its surrounding ecosystem, we believe that specific predictions concerning the effects of the dam operations on the rainbow trout fishery and its surrounding ecosystem can be made and tested with the next flow manipulation. The biologists working on the fishery have these ideas in mind, but we suggest that they be formalized as testable predictions resulting from formal hypotheses. Moreover, these hypotheses should relate flow manipulation to the rainbow trout fishery, other fish species, phytoplankton, macrophytes, periphyton, the invertebrate food base, and physical and chemical conditions, such that potential mechanisms producing effects can be considered. Perhaps the ecosystem model developed by Walters could be used to develop such hypotheses and predictions. Once these hypotheses are formalized, the specific methods to test them should be clearly defined. **Second,** the biologists working on the rainbow trout fishery should begin to forge links with the physical scientists and with the biologists working on Lake Powell, on the downstream Colorado River and on the surrounding terrestrial systems. Although working with all these groups at once would be impossible, we suggest that the biologists develop a list of links to these other ecosystems that they hypothesize are related to the rainbow trout fishery. After the links have been determined, biologists could prioritize the list based on “best available” information. Those links that are deemed most important could be examined first, presumably this would result in a smaller list of connections to explore.

2.6 Monitoring protocols should be optimized to maximize statistical power while minimizing collection of unnecessary information

The current rainbow trout sampling protocol can be evaluated according to several criteria including: 1) agreement with requirements set forth in the Grand Canyon Monitoring and Research Center Long-term Monitoring and Research Strategic Plan (Garrett et al. 1997); 2) the extent to which the protocol provides information that allows evaluation of stakeholders' rainbow trout management objectives; 3) the extent to which it satisfies objectives listed in the rainbow trout monitoring Request For Proposals (RFP) (Grand Canyon Monitoring Research Center 1997); and 4) statistical soundness.

1) Meeting Strategic Plan Objectives: The current monitoring protocol provides for collection of information on abundance, population size, size structure, growth rates, and recruitment, thus satisfying requirements set forth in the Grand Canyon Monitoring and Research Center Long-term Monitoring and Research Strategic Plan (Garret et al. 1997).

2) Meeting Stakeholder Objectives: Monitoring results presented by David Speas and Bill Persons (AGFD) show that: >50% of the Lee's Ferry rainbow trout population recruitment is due to natural reproduction; the Lee's Ferry rainbow trout population increased from approximately 100,000 to 262,000 individuals between 1996 and 1999; total length attained by Age 3 fish was <18" in 1999; and that condition (relative weight) was 0.77 in 1999. Thus, data collected under the current protocol allow objective evaluation of stakeholders' rainbow trout management objectives (Table 1), although some data are likely to be biased (see Statistical Soundness, below).

Table 1. Stakeholders' management objectives for the Lee's Ferry rainbow trout fishery.

Management Objectives	Initial (1996)	Updated (2000)	Objective met (2000)
Proportion of population due to natural reproduction	50%	>50%	Yes
Total population of Age 2+ rainbow trout	100,000	262,000	Yes
Total length by Age 3	15"	18"	No
Condition (relative weight) of Age 3 rainbow trout	≥0.80	≥0.90	No

3) Meeting project objectives of the Request for Proposals: The current monitoring protocol addresses all stated project objectives of the RFP (Table 2). These objectives include: (1) a report synthesizing existing information on the Lee's Ferry rainbow trout fishery (this report has been completed); (2) electrofishing has been used to monitor abundance and recruitment and to collect fish for measurement of length, weight, sex, and reproductive status; (3) methods have been developed to determine the proportion of the population that is naturally spawned; (4) condition indices are calculated from length and weight measurements and a health assessment index was developed, evaluated, and found to be uninformative; and (5) potential changes in fish condition are being assessed.

Table 2. Project objectives listed in the (1997) request for proposals to monitor the rainbow trout fishery of the Colorado River downstream from Glen Canyon Dam to Lee's Ferry (Garrett et al. 1997).

	Objective	Objective met
1	Synthesize existing information (published and unpublished) on the Glen Canyon/ Lee's Ferry trout fishery and determine the fishery's likely response (growth, reproduction, recruitment, population structure, size and distribution) to dam operations.	Yes

2	Monitoring activities for determining population size, structure, growth, distribution, reproductive success and overall recruitment in response to dam operations.	Ongoing
3	Development of methods for estimating the proportion of natural reproductive success in combination with stocking quantities and rates to determine desired levels of recruitment balanced against the carrying capacity for a range of dam operations.	Ongoing
4	Develop evaluation criteria for, and measure and assess the health and condition of the rainbow trout population.	Ongoing (health assessment discontinued)
5	Evaluate changing health and condition factors in relation to changes in the aquatic food base and nutrient levels determined in the food base RFP.	Ongoing

2.6.1 Statistical soundness of the current electrofishing sampling protocol

The current rainbow trout monitoring protocol comprises three sampling events per year, in April, August, and November. Each of nine sites is sampled by electrofishing for 33.3 minutes during each sampling event. Sampling is conducted on three successive nights, with three sites sampled each evening. All captured fish are measured (total length, TL, mm), weighed (g), sexed, and examined for the presence of PIT and coded-wire tags. PIT tags are used to allow mark-recapture estimates of rainbow trout population size; however, AGFD personnel indicate that most recaptures are from the area in which fish were initially captured, tagged, and released. This apparent behavior violates a critical assumption of mark-recapture estimates, that marked fish mix freely in the entire population. The possible effects of this violation on population estimates need to be studied.

The current monitoring protocol has limited power for detecting short-term changes in rainbow trout abundance (CPUE, catch per unit effort), such as might be expected to occur as a result of experimental manipulation of discharges from Glen Canyon Dam. It is probable that power can be increased by increasing the number of sites sampled to 15, the number of sites used from 1991 through 1997, and decreasing the time spent at each site proportionately (i.e., to 20 minutes, based on 15 sample sites) so that total sampling time (300 minutes per sampling event) remains constant. Based on preliminary power analyses presented by David Speas (AGFD), this change should increase statistical power for detecting short-term changes in abundance by approximately 63%. To be sure, cutting the time per site would still not fully balance out the additional time required to analyze more groups of data, but the increase in precision would be helpful. Assuming there is no systematic change in electrofishing catch rate at a given site during a given sampling run (i.e., catch rates are similar at the beginning or end of a sampling run), increasing sampling site number and decreasing sampling time at each site will have no effect on estimates of CPUE. Using estimates of between-site variability, measurement error as a function of time spent within a site, set up time at a site, and travel time between sites, one should be able to get a rough idea of the best compromise between sites and time within sites.

A random approach stratified by geomorphic reaches has been suggested for the sampling approach to be used for both the terrestrial and aquatic resources downstream. Our understanding is that the original 15 sites were chosen based roughly on a stratified (by geomorphology) random approach. If the Lee's Ferry section of the river has already been broken into unique geomorphic units one should 1) determine a very rough estimate of the trout densities in the different unit types, 2) determine the geomorphologic type for each of the units that are currently sampled, 3) estimate the approximate proportion of the different unit types that should be measured, 4) determine whether the current geomorphic sampling proportions are approximately correct. Here GCMRC could replace geomorphic with any other appropriate habitat designation. We note that spending a lot of time sampling where fish are absent adds little information to an overall estimate, so perhaps the current allocation of effort is probably not too far off. Adding a few more sites (and perhaps removing a few) might be all it takes to produce a sensible allocation. Overall, however, because a long time series exists for the current sites we recommend that GCMRC be very careful about removing sites.

Biases arise if GCMRC and AGFD have adapted their electrofishing regimens to optimize their information on the abundance of RBT at those sites where fishermen can catch them, that is, making the electrofishing and the creel data correspond with respect to the sites sampled by AGFD and fishermen, respectively. This approach only provides information on how the catchable RBT population varies at the fishable sites, but probably would NOT help understand the effects of discharge on recruitment of YOY or the production of 19 in fish. For example, if the proportion of fish in each of the different habitat type stays about the same, the current method probably provides a sufficient index. However, if the proportion changes from year to year (maybe marginal sites are only occupied in good years?) then it is important to sample each of the units that could potentially have a significant number of fish. Again, if one knows for certain that particular types of units have very few trout then one should spend little time sampling them.

The current monitoring program has considerable power to detect fairly small changes in size structure, weight, and condition (K_n) in rainbow trout populations, provided that there are no major changes in discharge that affect fish distribution. Currently, all fish captured during electrofishing are measured (TL), weighed, sexed, and are examined for PIT and coded-wire tags. Considerable time is spent handling fish. Objectives for use of length and weight data should be clearly specified and a power analysis undertaken to determine the maximum number of fish per sample that need be weighed and measured. This will allow additional time for other monitoring activities and minimize handling and stress for rainbow trout- an expressed concern of one stakeholder (Trout Unlimited).

The current sampling design, at best, may be described as fixed-site sampling, with sites initially chosen at random. Although this design seems to be a good compromise between subjectively (nonrandomly) chosen fixed sites and probability sampling (stratified random), it potentially fails to capitalize on the benefits of probability sampling: probability sampling allows that, on average, unbiased estimates will be obtained. However, there is no guarantee that any single set of sites will provide an unbiased estimate. Finally, because sample sites do not appear to be representative of all available habitats, electrofishing results cannot be extrapolated to provide an independent estimate of population size. Such an estimate would be valuable in confirming population size estimated by mark and recapture (PIT tags) techniques. If sampling sites are not representative, potential changes in rainbow trout population size (based on catch rates) and condition may be obscured. Changes in population size in (unsampled) poor habitat may occur well before similar changes in (sampled) better habitat because, during times of population decrease, fish may move from poorer habitats to occupy open areas in better areas. Many of these potential shortcomings in the sampling design can be overcome by modest revisions of the sampling protocol.

Sampling sites were chosen based on their use in previous monitoring work. While this previous work used 15 sites, in ongoing monitoring, the number was reduced to nine sites that were purportedly chosen according to a stratified random design. The panel questions whether these sample sites were chosen from among all available habitat types or only those that were believed to represent “good” trout habitat. All sampling sites shown to the panel appeared to represent relatively shallow, near-shore gravel and cobble bars. Deeper sites along canyon walls and in the main channel, for example, were not sampled. Admittedly, the latter sites may be difficult to adequately sample; however, the panel was provided anecdotal evidence that large rainbow trout inhabit the main channel suggesting a potential bias in estimates of population size structure.

Alternate sampling procedures, e.g., snorkel surveying and various traps, provide good ways of supplementing the electrofishing data. Snorkling is faster, has less impact, and has the potential for detecting YOY and large adults, in addition to the narrower size range of fish collected by electrofishing. It also allows one to see which microhabitats the fish are using and to record differences in fish behavior with habitat, site, and time. Minnow traps and hoop nets allow processing of actual fish samples without the injuries inherent in electrofishing. All of these sampling methods will allow sampling of habitats that are unsuitable for electrofishing, as well as providing alternate methods from sampling sites that are appropriate for electrofishing.

Temporal variation in trout populations are currently followed by repeating the electrofishing surveys three times per year (April, August, and November), times chosen to "coincide with seasonal changes in densities (benthic macroinvertebrate abundance and drift) of the aquatic food base" (Persons 1997). We are not convinced that increasing the sampling to 4 or more times per year will automatically increase the quality of the information obtained. It seems that the current 3 times per year sampling adequately samples the terrestrial seasonality of the system. Additional sampling might be better directed specifically at the effects of discharge variation on habitat changes and the survival and growth of YOY trout.

2.6.2 Creel sampling of the Lee’s Ferry fishery should be continued

The creel survey continues to provide critical information about the trout population to the AGFD, while providing a critical opportunity for information exchange between AGFD and an very important stakeholder group, and therefore needs to be continued. Given the facts that the rainbow trout, an introduced species, is the sole fish taken at this site, and that it is primarily a catch-and-release fishery, one could say that one should abandon all other sampling before abandoning the creel. Nevertheless, the GCMRC remains responsible for collecting data to determine the impacts of discharge management plans, and the creel provides more information on how discharge affects fishermen than on how it affects fish, so other sampling is still needed. For example, both whirling disease and discharge changes could profoundly affect recruitment, but the creel would not provide much information on the functional relationships between either of these factors and the trout population. Creel surveys take advantage of a vast amount of fishing effort to estimate CPUE, providing an additional index of population size that can be used to validate other sampling methods. The creel provides (statistically noisy) estimates of fish size frequency that are useful for tracking changes in size composition. The single access point for the Lee's Ferry fishery makes the creel survey an especially easy (and cost effective) way to simultaneously collect CPUE and fisherman opinion data. The current approach seems reasonable but we recommend analyzing existing data to determine how sampling different numbers of days per month and stratifying by different covariates (like weekend/weekday, month, etc.) will affect variance of the estimates (CPUE, size structure, etc.).

2.6.3 Sampling for young of year fish should be added to the current monitoring protocol

Available data and on-site observation of electrofishing operations strongly suggest that the current monitoring protocol severely underestimates the number of small < 152 mm fish in the population. In 1996 and 1997, a period marked by abundant natural recruitment, fish < 152 mm represented 30 to 40% of the total population. Given that the rainbow trout population increased by 40% during this period, it is likely that young fish, < 152 mm, were under represented in electrofishing samples.

Because electrofishing does not recover juvenile trout, it provides little information on recruitment. Because reproduction and recruitment appear to be occurring year round, the effects of discharge cannot be assessed through sampling at one or a few times per year as is characteristic for management of other salmonids. Nevertheless, it seems likely that variation in discharge will most profoundly affect juvenile fish survival and growth since the characteristics of gravel bars and the presence of backwaters are sensitive to discharge and water level in the Lee's Ferry reach of the Colorado River. Assuming that YOY are closely associated with the bank, we predict that a snorkel survey of the bank would provide good YOY estimates. Minnow traps may also be useful. However, expending a lot of effort on getting accurate estimates of YOY when GCMRC is only sampling a small subset of the available shoreline is probably not an efficient use of time. One way of determining the importance of accurate YOY estimates is by seeing how sensitive the population dynamics model is to changes in YOY values. Whereas getting a rough estimate of YOY abundance should be relatively easy in conjunction with information on discharge, we recommend making sure the sampling is necessary before expending more effort to obtain the data. As will be seen below, considerations of potential impact of whirling disease may provide an additional rationale for sampling YOY.

2.6.4 Monitoring for whirling disease should be added to the monitoring protocol

Because rainbow trout in the Colorado River are positive for whirling disease upstream from the Lee's Ferry Reach, and the disease can cause high mortality of infected juveniles, monitoring for *Myxobolus cerebralis* should be included in the routine monitoring protocols. Although the Lee's Ferry rainbow trout are isolated and the cold hypolimnetic release does not favor whirling disease, there is still a high probability that the disease will eventually affect the Lee's Ferry trout population. Unfortunately, whirling disease seems to cause its most devastating effects in very productive trout fisheries like that of Lee's Ferry. Whirling disease can infect fish when water temperature is 8º C and becomes really infective at about 12-15ºC. Although the Glen Canyon dam discharge is only 8º, the temperature of the river increases as one goes downstream, so that the probability of whirling disease being a problem increases as one goes downstream.

Several monitoring methods could be used. First, some fish could be sacrificed during fish sampling and subsequently be examined histologically and/or using PCR techniques to detect *Myxobolus cerebralis*. This would be biased somewhat toward larger fish (since the current sampling protocol is biased) and would not be an early alert to whirling disease in the system. Second, perhaps if sampling protocols are modified such that smaller, young fish are adequately sampled, a subsample of them could be tested using either PCR and/or histological techniques. The problems with both of these methods is that very sick fish die early, so the level of infection is often underestimated and because fish move we do not know exactly where they were infected. Third, sentinel cages containing young hatchery fish that are held for 10 days in the stream and 80 days in a holding facility (for spores to mature and end up in head cartilage) and then subsequently examined histologically is an effective way to detect infecting spores, and will provide the best chance of early detection of whirling disease at Lee's Ferry.

3. CONCLUSIONS

The panel is impressed with the efforts made by the GCMRC, AGFD, and others in studying and monitoring the rainbow trout population in the Lee's Ferry reach, and with the care by which the results of their research and monitoring have been recorded in published literature and reports. The availability of this extensive written record, and their willingness to show us the sampling sites and to present the results of their research made our work possible.

The panel recommends that GCMRC develop an explicit set of ecologically-based Study Objectives, based on desires of stakeholders, that will drive all activities, including design of Requests For Proposals, and that the AGFD take an active role in communicating this process to stakeholders. The panel found, like other reviewers before it, that a more integrated research program would benefit the adaptive management of the Glen Canyon and Grand Canyon resources, and that the GCMRC should work to achieve this goal through providing leadership among stakeholders and researchers alike. Further, the GCMRC should work to promote communication and outreach of Grand Canyon research to stakeholders and the broader research community. While the Trout PEP was charged to assess current monitoring protocols of the rainbow trout population, it is clear that an integrated view of the river that includes both upstream and downstream areas as well as terrestrial habitats is required. The specific sampling protocols could be improved by increasing the number of electroshocking sampling sites back to 15, while sampling at each site for a shorter period of time, and adopting a truly random sampling site selection approach. The current sampling protocol is biased against small rainbow trout and those fish living in the main channel and along steep canyon walls, and habitats that might be viewed as "poor" trout habitat. Because current sampling sites are not representative of all available habitats, electrofishing results cannot be extrapolated to provide an independent estimate of population size. Similarly, the trout's tendency to stay in one place violates an important assumption of the use of tagging studies to measure total population size, namely that tagged fish mix randomly with the total trout population. The creel sampling was found to be valuable in managing the fishable population of trout and in maintaining contact with an important group of stakeholders, the fishermen. Sampling protocols should be expanded to include monitoring of young-of-year populations and for the occurrence of whirling disease.

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