Evaluation of the Breeding Riparian Birds Monitoring Program for the Colorado River Ecosystem, through 2000

Final Report

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

SUMMARY

This report consists of a critical evaluation of the avian monitoring projects within the Colorado River Ecosystem (CRE) initiated by the Bureau of Reclamation (BOR) Glen Canyon Environmental Studies Program (1982), and continued by the Grand Canyon Monitoring and Research Center from 1996 through 2000. Our assessment summarizes the strengths and weaknesses included in the final products of the avian monitoring projects, and includes the identification, refinement, and development of the key components of monitoring, including the development of a conceptual model linking the effects of differing Glen Canyon Dam operations to impacts on the CRE riparian vegetation and avifauna. We also recommend further steps that will be required for designing an effective CRE avian monitoring program. Thus, this report is specifically designed to provide GCMRC with readily useable information that is needed to link monitoring to CRE decision-making.

PART 1: INTRODUCTION, OBJECTIVES, AND CRITERIA USED IN THE ASSESSMENT

Introduction

The BOR Glen Canyon Environmental Studies Program (GCES), between 1982 and 1995, initiated research studies and monitoring activities to determine baseline conditions and associated changes in many physical, biological, cultural, and socioeconomic resources within the Colorado River Ecosystem (CRE; Garrett et al. 1997). This research included several bird studies. When the Grand Canyon Monitoring and Research Center (GCMRC) was formally established in 1995, a long-term monitoring and research Strategic Plan, (i.e., Garrett et al. 1997) was developed, in response to the 1992 Grand Canyon Protection Act (GCPA) and the Glen Canyon Dam Environmental Impact Statement (USDI BOR 1995) directive to the Secretary of the Interior, "To establish and implement long-term monitoring programs and activities that will ensure that Glen Canyon Dam is operated in a manner consistent with that of Section 1802..." of the GCPA. All of the programs developed under the Strategic Plan were meant to "relate to determined or potential resource impacts primarily in the Colorado River corridor between Glen Canyon Dam (GCD) and Lake Mead resulting from ‘The effects of the Secretary’s actions” (i.e., dam operations or alternative dam operating criteria as well as other authorized actions; Garrett et al. 1997).

Several overlapping and consecutive terrestrial bird studies have been conducted over the years under the auspices of the GCES and the GCMRC. Some focused on endangered or select bird species (e.g., Brown et al. 1983, Brown 1988a, Brown and Trossett 1989, Brown and Stevens 1992; Sogge and Tibbitts 1993, 1994; Sogge et al. 1997). Others described the riparian bird community and initiated the establishment of bird monitoring, including Brown (1988b), Brown and Johnson (1985, 1987, 1988), Brown et al. (1987), Sogge et al. (1994, 1995, 1998), Grahame and Pinnock (1995), Petterson and Spence (1997), Spence (1996, 1997), Spence et al. (1998, 1999), and Spence (2004).

Objectives

We undertook this assessment of the design of the long-term avian monitoring program of the GCMRC and past avian monitoring projects within the CRE to: 1) determine whether the monitoring designs (both within the Strategic Plan and individual avian monitoring projects), and the methodologies employed for monitoring, enable detection of environmental change at appropriate spatial and temporal scales, provide insights to the ecological consequences of these changes, and help decision-makers determine if the observed changes warrant any changes in current management practices (e.g., Noon et al. 1999), and, 2) determine if the avian monitoring projects have met the goals of the GCMRC, and the objectives and information needs identified in the Strategic Plan. Based on our evaluation of past GCMRC avian monitoring projects we develop a conceptual model and make recommendations for the selection of appropriate indicators and for designing an effective long-term monitoring program in the CRE.

Overview of Criteria for Effective Ecological Monitoring

Public lands are managed with an overriding constraint that species, ecosystems, and processes be sustained on the landscape while allowing a variety of other activities to be conducted. This constraint is addresses by federal legislation including the National Environmental Policy Act, Fish and Wildlife Conservation Act, Migratory Bird Treaty Act, National Park Service Organic Act, and the Endangered Species Act (Hutto and Young 2002). To ensure that these processes are being sustained, species' population trends must be tracked and the effects of natural and human-caused disturbances must be measured; i.e., monitoring programs are essential.

Monitoring programs generally fit into one of two categories; 1) Long-term Monitoring Programs (LTMPs) and, 2) Adaptive Management Monitoring Programs (AMMP). Avian LTMPs are designed to monitor population trends. They use methods that provide an index of abundance (e.g., point counts) and do not include demographic data (e.g., nest success). LTMPs are useful for discovering if populations are in decline and they can provide information on habitat associations (i.e., which species are found in what habitat). Thus, LTMPs that provide such information can be used to identify target species for which mechanistic studies should be established to gain insight into the causes behind measured population level differences (Hutto and Young 2002). In addition, LTMPs can be used to establish baseline values on the distribution and abundance of specific species from which future comparisons can be made over time. In contrast, AMMPs involve relatively short-term monitoring of causes and effects that provide information to be used in an adaptive management framework and/or in model development. This type of monitoring is sometimes called stressor-based monitoring, and quantifies relationships between identified response variables (e.g., bird abundance) and functionally related independent variables (e.g., habitat changes).

LTMPs have several limitations. The detection of trends requires large sample sizes, which requires sampling on a large spatial (e.g., large, ecosystem, to state, to national) and/or temporal (i.e., 10-20 years) scale. Consequently, if long-term monitoring is done on a limited spatial or temporal scale, the number of species for which you can attain reliable population trends are fewer than those that can be obtained from conducting monitoring at a larger scale (e.g., national, multiple years). Conversely, if done on a large scale, the resolution of the information is often too course for regional decision-making (Hutto and Young 2002). Perhaps the greatest limitation of LTMPs is that they are not very useful for discovering the reason behind the declines they do detect.

Monitoring programs that use experimentation and adaptive management (AMMPs), have more power to discern causes behind trends than population trend data from LTMPs (Nichols 2000, Hutto and Young 2002). For example, monitoring can be designed to elucidate bird-habitat relationships and describe land-use effects. Bird monitoring is then used as a tool for detecting the effects of current management practices (i.e., stressors). The detection of land-use effects can, in turn, allow for projection into the future, based on current land-use trends, and revision of activities that would otherwise generate negative bird population trends (Hutto and Young 2002). Thus, monitoring can be a proactive effort to understand the effects of persistent human activities (that can be modified).

A comprehensive monitoring program should combine both long-term monitoring and adaptive management monitoring that provides demographic data (Marzluff et al. 2000, Hutto and Young 2002). Abundance and count data from the LTMP can expose interesting habitat association patterns or land-use effects, while mechanistic studies based on demographic data are necessary to provide probable explanations for those abundance patterns (Hutto and Young 2002).

Given the extensive effort necessary to conduct meaningful monitoring, the utmost care should be taken in designing the monitoring so that it meets the goals and information needs of the organizations involved. Noon et al. (1999) identify key issues to address when designing a monitoring program. These include:

1) Specify goals and objectives.
2) Characterize stressors and disturbances.
3) Develop conceptual model linking stressors to ecological responses.
4) Select indicators responsive to environmental stressors.
5) Estimation of the status and trend of avian indicators/Establishment of sample design.
6) Establish "trigger points" for management intervention.
7) Establish clear connections to the management decision process.

We use these as criteria in our assessment of the Strategic Plan, which formed the basis for the various avian monitoring projects, and for assessment of each successive avian monitoring project. Below, we elaborate on each of these criteria and how we used them in our evaluation.

Specific Criteria for Assessment

<u>Criteria 1: Specify goals and objectives</u>

In order to design a relevant, cost-effective monitoring program, its goals and objectives must be clearly defined, along with the specific questions, parameters to be estimated, or hypotheses to be tested by monitoring. In our assessment we evaluate whether, in the Strategic Plan, the goals and objectives of the ecological monitoring of the GCMRC were clearly stated, especially in regards to avian monitoring. And, if so, were these goals and objectives addressed in the design of subsequent avian monitoring projects?

<u>Criteria 2: Characterize stressors and disturbances</u>

An initial step in designing a monitoring program should be the identification of anticipated extrinsic environmental stressors, both natural and human-induced, that may compromise ecosystem integrity and alter its component species and resources. If the effects of these stressors exceed the resilience or adaptational limits of the ecosystem, the ecosystem will change. This change may result in management goals being compromised, necessitating adapting management actions (Noon et al. 1999). Have potential stressors within the CRE been identified? In particular, have stressors that are subject to adaptive management (e.g. river flow rates, water temperature regimes, recreational use, land-use patterns in surrounding uplands) been identified? We assess the adequacy of the Strategic Plan and the avian monitoring projects' identification of stressors, in particular those resulting from management actions, especially those that may affect the avifauna.

The next step in monitoring design involves identifying the ecological resources that may be affected by these stressors. Did the Strategic Plan adequately identify these resources? Did the subsequent monitoring programs develop or incorporate this information in their designs? During this step in the assessment, we compiled an inventory, based on previous studies regarding the CRE, of the ecological attributes (both avian habitat components and bird species parameters) of the riparian habitat zone that are likely to be affected by stressors within the CRE.

Criteria 3: Development of a conceptual model linking stressors to ecological responses. A conceptual model is a visual or narrative summary that outlines the pathways from stressors to the ecological effects on one or more resources. Conceptual models of the resources of concern are a key tool for designing a monitoring program and form the basis for selecting indicators for monitoring (Noon et al. 1999). They are also useful for evaluating the integration of CRE bird and related vegetation studies, and the ability of the avian monitoring projects to determine linkages among the avifauna and resource components of concern. A well-designed model can enable predictions to be made regarding the effects of various management actions and thus can direct the design of an effective monitoring program. Rather than making specific predictions, a conceptual model can help guide further studies (NRC 1999).

Thus, as part of our assessment, we reviewed the design of the avian monitoring program, as described in the Strategic Plan and related documents, to ascertain how indicators were selected for monitoring, and if conceptual models were developed and used in the selection process. Did the avian monitoring projects determine linkages among the avifauna and resource components of concern, a stated goal of the GCMRC?

With information from our assessment of previous studies of the terrestrial ecosystem within the CRE we develop a conceptual model to identify known linkages among stressors and avian resources, to expose information gaps, and to provide information for forming hypothesis for testing in future studies of terrestrial birds in the CRE.

Criteria 4: Select indicators responsive to environmental stressors

The ultimate success or failure of a monitoring program may be determined by this one step of selecting indicators (Noon et al. 1999). The steps above, identification of stressors, the ecological resources affected by them, and development of conceptual models, enables a critical evaluation of the Strategic Plan and the avian monitoring projects' criteria for, and selection of, avian indicators. Do the avian parameters measured by the monitoring projects provide insights to the ecological consequences of dam operations? Do they enable prediction of how changes in the abundance and availability of ecological resources may affect bird species and assemblages? Do the response variables selected for monitoring by these projects serve as indicators of changes in key resources? Is it possible to examine species-specific data and identify assemblages, if any, of species that are similarly linked to resource attributes and/or stressors?

Criteria 5: Estimation of the status and trend of avian indicators/Establishment of sample design.

As described in our definition of long-term monitoring programs, information on the status and trend of species can be used to identify target species for which mechanistic studies can be established to gain insight into the causes behind demonstrated population level differences. In addition, this information can be used to establish baseline values on the distribution and abundance of specific species from which future comparisons can be made over time.

We evaluated the various avian monitoring projects use of sampling methodologies, and subsequent analysis and results, to assess whether these were adequate to provide unbiased estimators of avian abundance and the level of information needed to detect change over time.

First, we assessed the methods used to select sampling areas, to determine if the samples are statistically appropriate to characterize the scale of interest (i.e. the entire CRE). Specifically, we determined whether samples were randomly selected, stratified based on habitat characteristics, or selected as judgment samples, for which the biases and sampling errors can not be calculated from the sample but instead must be settled by judgment. Also, the detection of trends requires large sample sizes, which necessitates sampling on a large spatial and/or temporal scale. Do the methodologies employed in the avian monitoring projects produce adequate data to enable detection/measurement of changes in the avifauna (at both the species level and community level)? Does the sampling design allow for detection of changes in abundance of species of concern? Can long-term population trends of bird species be adequately monitored within the CRE?

In addition to evaluating the design and methodologies used in determining avian population trends, we incorporated the canyon-wide trend information with trend information from multiple spatial and temporal scales. We assessed which species found within the CRE are of concern at a state-wide, regional, and national scale using current Breeding Bird Survey trend results (Sauer et al. 2003), Partners in Flight state-wide Bird Conservation Plans (Latta et al. 1999), and published information. Comparing the patterns of these trends can aid in determining if the trends within the CRE are due to local perturbations/disturbances within the canyon, or are likely the result of factors occurring at larger scales, beyond the confines of the canyon. Also, by combining this information we assessed if these species can be effectively monitored within the CRE using existing protocols/methodologies, or whether there is a need to develop new methodologies. Additionally, we assessed whether previous studies have provided the information needed to identify attributes specific to the CRE that may contribute to its ability to provide long-term conservation benefits and maintain sensitive avian populations. All of this information is necessary to prioritize conservation and management efforts.

Criteria 6: Establish “trigger points” for management intervention.

Monitoring is conducted to track changes in an indicator, and only by comparing observed and expected (i.e., benchmark) values or trends in this indicator, can a determination be made about the effectiveness of management practices (Noon et al. 1999). The CRE is an extremely dynamic ecosystem, lacking a “steady state” on which to determine benchmark conditions, and avian populations within the CRE can be expected to vary considerably over space and time. Thus, benchmark conditions are likely to be best represented by a dynamic abundance distribution over determined spatial and temporal scales, rather than a single value of abundance. Then, at a given time, observed distributions can be compared to the benchmark distribution and the magnitude and pattern of deviation from desired conditions can be measured (Noon et al. 1999). Under an adaptive management framework, trigger points- the value of the indicator that, when reached, warrents management action-must be established.

We assessed whether the avian monitoring projects have provided the information necessary for the GCMRC to adequately determined benchmark values for measuring changes in avian populations, and to identify potential trigger points. We used the following criteria: (1) What was the expected/baseline state of the CRE chosen (e.g. estimated, “natural”, pre-dam conditions, or current conditions?); (2) Were the spatial and temporal scales chosen appropriate (based on information gained through development of conceptual models)?; (3) Does the data provided by these projects allow for periodic estimates of the direction and magnitude of indicator change?; (4) Was the level of change at which management action is required (i.e., trigger points/response criteria) identified? Is there sufficient information available to make this determination?

Criteria 7: Linkage of monitoring results to decision-making.

For a monitoring program to be of value it must be of use to decision-makers. This is especially true in complex systems such as the CRE, with multifaceted ecological responses to disturbance events. Thus, we assess the avian monitoring projects' abilities to provide the information required by the GCMRC's Adaptive Management Program to adjust activities to mitigate unplanned and undesirable outcomes.

This report consists of a critical evaluation of the avian monitoring projects and includes the identification, refinement, and development of the key components of monitoring, as described above, including the development of a conceptual model linking the effects of differing dam operation to impacts on the Colorado riverine ecosystem. It also recommends further steps required for designing an effective avian monitoring program. Thus, this report is specifically designed to provide the readily useable information needed to link monitoring to decision-making. Additionally, the information provided by this evaluation contributes to the GCMRC's studies of the effects of the operation of GCD on downstream resources along the CRE and contributes to meeting the statutory requirements placed on the Secretary of the Interior by Congress via the 1992 Grand Canyon Protection Act, the 1995 Glen Canyon Dam Environmental Impact Statement, and the 1996 Record of Decision (ROD)(GCMRC website).

PART 2: THE ASSESSMENT

As discussed, to design a meaningful monitoring program, each of the criteria detailed above should be addressed. The Strategic Plan is the result of the initial design process for long-term monitoring in the CRE. It identified the goals and information needs of long-term monitoring and selected the indicators to be monitored. Thus, it was meant to form the basis for the subsequent avian monitoring projects. During the monitoring design process conducted to produce the Strategic Plan, it would have been appropriate that the initial criteria for designing a meaningful monitoring program be addressed. These include the specification of goals and objectives, characterization of stressors and disturbances, development of conceptual models, and the selection of indicators to be monitored. Subsequent avian monitoring projects would then address the additional criteria including, estimation of the status and trend of indicators, establishment of "trigger points", and connecting monitoring results to the management of the CRE.

Initial Design of the GCMRC Long-term Monitoring Program

Specification of goals and objectives

The primary steps in designing a relevant, cost-effective monitoring program are to clarify the goals of the program (i.e., the reasons for monitoring), and identify the information the program needs to provide. Planning for long-term monitoring in the CRE was initiated by the GCES and the Glen Canyon EIS management agencies in response to the Grand Canyon Protection Act of 1992. The proposed goals and purposes of the initial Long-term Monitoring program (Patten 1993), in particular the objectives of the terrestrial monitoring program, were vague and difficult to interpret (NRC 1994). It did not explicitly assign priorities for monitoring or identify specific research recommendations (NRC 1994). These initial goals and objectives were revised and expanded upon when the GCMRC developed the goals and information needs for long-term monitoring in the CRE, during the creation of the long-term monitoring and research Strategic Plan, which was designed to respond to the objectives and information needs of stakeholders and managers (Garrett et al. 1997). In it the overall goal for monitoring is broadly defined; all of the programs developed under the Strategic Plan were meant to "relate to determined or potential resource impacts primarily in the Colorado River corridor between Glen Canyon Dam (GCD) and Lake Mead resulting from the 'The effects of the Secretary's actions' (i.e., dam operations or alternative dam operating criteria as well as other authorized actions"; Garrett et al. 1997). Currently, the goals of the GCMRC are similarly stated, "to develop monitoring and research programs and related scientific activities that evaluate short-and long-term impacts of the Glen Canyon Dam on the biological, cultural, and physical resources of the Colorado River Ecosystem. The GCMRC also provides information concerning resources of the CRE specified annually by the Adaptive Management Work Group (AMWG) and the Secretary of the Interior" (www.gcmrc.gov 2004).

Within the GCMRC Biological Resources Program, the purpose of the research and monitoring programs are more extensive than that listed for the other programs in that, in addition to providing information on the impacts of differing dam operations on the ecosystem and associated flora and fauna, the Biological Resources Program's research and monitoring programs are also intended to "develop information about the structure and function of the Colorado River ecosystem" (Garrett et al. 1997). The Strategic Plan also calls for integrating parameters for monitoring: "It is key that relationships between the biotic and abiotic components of the CRE be addressed to predict impacts on critical biological resources". Specifically, the Strategic Plan proposed that changes in the three primary riparian zones be monitored, and monitoring of faunal assemblages (e.g., riparian birds) be aligned with the sampling of riparian vegetation habitat changes.

As described in the Strategic Plan, Garrett et al. (1997), *monitoring* is to occur on all resources of concern, to determine changes in resource attributes. The physical scope of the program is limited to primarily the Colorado River mainstem corridor and associated riparian and terrace zones from the forebay of GCD to the upper reaches of Lake Mead. *Research* is to "be used to interpret and explain trends observed from monitoring, to determine cause and effect relationships and research associations, and to better define interrelationships among physical, biological and social processes." The research scope includes limited investigations into side tributaries such as the Little Colorado and Paria Rivers. Thus the GCMRC, in the Strategic Plan, implicitly recognized the need for both LTMPs and AMMPs that we have described above.

Characterization of stressors and disturbances, development of conceptual models linking stressors to ecological responses, and selection of indicators responsive to environmental stressors.

Pertinent to our assessment, the Strategic Plan identified the need for many of the key components in designing a monitoring program that we have described above. It states that several actions "are necessary to ensure progressive future monitoring and science programs." These include:

1. Implement an adaptive management process to facilitate close interaction of science and management in applying new management criterion and evaluating the impacts of those criterion.
2. Development of a conceptual model of the Colorado River ecosystem to define critical attributes within resource categories, critical attribute linkages across resource categories, and interdependencies of resource attributes.
3. An extensive synthesis and state-of-the-science assessment of all past knowledge associated with pre-dam baseline resource conditions in the CRE, riverine resource conditions associated with construction of the GCD, and changes associated with "the effects of the Secretary's actions".
4. Ecosystem analysis to improve understanding of the most critical attributes thought to be drivers of change of individual resources and groups of resources, and the interdependencies of attributes within and across resources.

In particular, the Strategic Plan recognized the need for, and utility of, conceptual models for describing the relationships that are believed to be important factors affecting the behavior of the system. It states, "Conceptual models can aid in identifying crucial components of the ecosystem for monitoring, and developing hypotheses for testing assumptions about the factors believed to affect the dynamics of the system. For example, they are important tools for designing research that examines cause and effect relationships so that this information can be used as a basis for predicting the ecological consequences of alternative management practices, and to discern the relative importance of various factors that may impact ecosystem function and provide predictive linkages between species, communities, and the physical setting, as called for in the Strategic Plan." In particular, the National Research Council saw the development of a conceptual model as an essential step in the selection of environmental parameters to be modeled (Garrett et al. 1997). Yet, despite acknowledging their value, stressors were not identified and conceptual models were not developed. Thus, factors that link processes and would therefore be priority indicators for monitoring under the Strategic Plan, were not identified (NRC 1999). In effect, these procedures were skipped over in the selection of indicators for long-term monitoring, including terrestrial avifauna.

Instead, the Strategic Plan relied upon information derived from previous and contemporaneous studies conducted by the GCES, particularly in regards to development of monitoring programs for terrestrial resources, including riparian birds. These GCES studies had the broadly defined goal to determine baseline conditions and dam-associated changes in many physical, biological, cultural, and socioeconomic resources within the CRE (Garrett et al. 1997). They included a limited number of riparian studies and several bird studies and, due, at least in part, to this broadly defined goal of the GCES, the specific objectives and subsequent designs of the GCES bird studies were diverse and relatively unrelated. The GCES bird studies linked to terrestrial resources focused on endangered bird species (i.e., Bald Eagle (*Haliaeetus leucocephalus*), Peregrine Falcon (*Falco peregrinus*), Southwestern Willow Flycatcher (*Empidonax trailii extimus*), and riparian bird species (e.g., Brown and Johnson 1985, 1987, 1988; Brown et al. 1987, Brown and Trosset 1989, Grahame and Pinnock 1995). The information from these studies, despite acknowledging the need for a "synthesis and state-of-the-science assessment", as described under 3, above, was not assessed/synthesized prior to the selection of indicators; this occurred later, in Patten (1998) and NRC (1999).

Sogge et al. (1998) did address the applicability of previous GCES bird studies to community level (i.e., riparian breeding bird) questions. Studies of single species (e.g., Brown 1988a, Sogge et al. 1997) or indicator species (e.g., Brown and Johnson 1987, Brown 1988b) are not useful for predicting long-term trends in the riparian breeding bird community as a whole (Sogge et al. 1998). In addition, many of these studies focused on a small number of study sites (e.g. Brown and Johnson 1987; Brown 1988a, 1988b) and/or measured fine-scale, within-patch habitat features, severely limiting the extrapolation of their results to larger scales (Wiens 1989) including the CRE (Sogge et al. 1998). These terrestrial bird studies failed to examine the effects of dam operations on the riparian bird community and they were not designed to address long-term monitoring. Most focused on the apparent increase in the diversity and abundance of birds, believed to be due to the increase in New High Water Zone (NHWZ) vegetation relative to pre-dam conditions. Therefore they inferred the effects of the dam itself, not the effects of dam operations on downstream resources. Brown (1988b) did address the topic of monitoring and reported that trends (measured over only a few years) in five riparian species "were not found to be useful as a guide to understanding long-term trends in the density of the entire riparian breeding bird community." He also examined the direct impact of dam operations (i.e., flooding) on marshes and the apparent decline of the Common Yellowthroat (*Geothlypis trichas*), a marsh breeding species. Significantly, he acknowledged that, "future research should be focused on why the patterns and trends occur in order to firmly establish the indirect, more subtle links between dam operations and breeding birds".

One terrestrial bird study, conducted by Sogge et al. (1998), did have specific objectives to study the impacts of GCD, including both the direct effects of interim flow operations and the long-term effects of dam operations on the bird community. They also tested methodologies for long-term avian monitoring. This study provided much of the pertinent information available on the riparian breeding bird community and habitat associations in the CRE. They developed models and identified habitat features that can be used to predict bird abundance, species richness, and diversity. These models predicted:

1. Flow patterns that result in smaller, more isolated habitat patches would decrease bird numbers, richness, and diversity.
2. Flow patterns that create larger and more contiguous habitat patches will increase bird abundance and richness, within the constraints of local topography and geomorphology on patch size.
3. Loss of mesquite vegetation will decrease bird abundance.
4. Increases in the number of habitat patches will increase overall number of birds and bird species in the canyon.
5. Changes from tamarisk shrub/tree to willow shrub/tree are not likely to greatly affect bird abundance and species richness.

For long-term monitoring this study suggested measuring habitat variables that predicted bird numbers, richness, and diversity using aerial photography, remote sensing, and GIS. They also cautioned against using bird diversity indices in long-term monitoring.

The fieldwork for the Sogge et al. study was conducted from 1993-1995, prior to the formation of the GCMRC, but the final report was not completed until after the completion of the Strategic Plan. It is apparent that some of the preliminary results from this study were considered during the development of the GCMRC's goals and information needs in the Strategic Plan, but it states that "riparian faunal habitat relations have not been well established in the Grand Canyon" (Garrett et al. 1997). Ultimately, the information provided by the other GCES studies (e.g., Brown et al. 1983, 1987; Brown 1988a, 1988b; Brown and Johnson 1985, 1987, 1988; Brown and Trossett 1989, Brown and Stevens 1992; Grahame and Pinnock 1995, Petterson and Spence 1997, Spence 1996, 1997) strongly influenced the subsequent development of the goals and information needs of the GCMRC's Strategic Plan regarding avian monitoring. In fact, birds were chosen for monitoring without first developing a conceptual model for exploring their potential for linking processes, or reflecting effects of management actions, and without formulating hypotheses regarding cause and effect relationships and resource associations.

Instead, the Strategic Plan specified needs in nine different resource areas: hydropower, water, sediment, fish and aquatic, biology riparian vegetation, threatened and endangered species, terrestrial wildlife, cultural, and recreational resources. The BOR and AMWG cooperatively developed specific objectives within each of these resources. Then, under each of these resources and specific objectives, GCMRC and AMWG cooperatively developed detailed information needs. These objectives and information needs then became the basis for the development of both the monitoring and research programs within four general program areas, i.e., physical, biological, socio-economic, and cultural. Within these program areas, Critical Attributes were identified; the responses of these Critical Attributes were to be used in adaptive management decisions, under the long-term monitoring program (Garrett et al. 1997). The Critical Attributes referred to in the Strategic Plan are what we have previously termed Indicators for monitoring. The Critical Attributes identified in the Strategic Plan that correspond with the long-term bird monitoring projects include: Wildlife and wildlife habitat: a) Area and species composition of riparian habitat for associated vertebrates; b) aquatic food base for terrestrial vertebrates, and; c) Endangered and other special status species, their habitat and food base: bald eagle, peregrine falcon, southwestern willow flycatcher, belted kingfisher, and other federal and state species of concern.

As stated above, bird studies conducted before and during the development of the Strategic Plan, rather than the synthesis of existing information and the development of conceptual models, guided the design of the GCMRC's monitoring program, including its selection of birds as indicators to monitor. The Strategic Plan states that avifauna was chosen for monitoring because:

1. Birds are "especially conspicuous and are trophically significant secondary consumers, integrating habitat structure, food resource production and predator populations".
2. "The Grand Canyon serves as an important flyway and stopover location for migratory waterfowl, raptors and passerine species."

3. Several avian species are federally listed as rare and endangered, or are considered for listing (at the time the Strategic Plan was developed; Garrett et al. 1997).

While terrestrial birds are significant secondary consumers and may serve to link habitat structure, food resource production, and predator populations, the potential linkages between terrestrial birds, these factors, and dam operations were not explored during the design of the monitoring program. Therefore it is not clear how birds can serve as adequate indicators of the ecological effects of dam operations. Perhaps the primary reason birds were chosen for monitoring was because several bird studies had been conducted, and were ongoing during development of the Strategic Plan. These studies led to the opinions expressed under 1 and 2 above, and some had also focused on the bird species that were federally listed and thus required monitoring. It is also likely that birds were selected as indicators because, in general, birds are considered a useful monitoring tool in that they are distributed over a wide geographical area and are numerous, their abundance can be can be estimated with relatively low impact, and the costs of measurement are usually not prohibitive.

Under the Strategic Plan, avifauna monitoring was to "emphasize the Southwestern Willow Flycatcher and general riparian avifauna (e.g., wintering and breeding waterfowl, riparian obligate species, resident non-obligate species and migrant species) in a biogeographic/geomorphic/seasonal context." The Strategic Plan also states that data from the avian monitoring program will be used in concert with regional population data to permit systematic evaluation of changing population sizes. Additionally, it called for the long-term monitoring program to "use methodologies that offer appropriate information about the response of the critical attributes to enable the AMWG to evaluate changes in light of the overall management objectives for resources of the Grand Canyon ecosystem" (Garrett et al. 1997).

The year following completion of the Strategic Plan, a synthesis of the information about the CRE, as called for in the Strategic Plan, was submitted to the GCMRC. This document (Patten 1998) was meant to integrate and evaluate the many studies “that report on response of Grand Canyon riverine attributes to dam operations” and evaluate “their contribution to our understanding of the integration of driving factors and response resources within the canyon.” In particular this report was designed to elucidate some of the interrelationships among CRE components, which “should guide future research and monitoring efforts”, and help to ensure that they are designed in an integrated fashion (Patten 1998). Thus, the goal was to provide information to meet three of the criteria for designing an effective monitoring program: (1) characterization of stressors and disturbances, (2) development conceptual models that link stressors and ecological responses, and (3) selection of indicators that are responsive to dam operations. Unfortunately, the very useful information from this report was not available at the time the Strategic Plan was developed and indicators for monitoring were selected, nor was it referred to in the subsequent design of the avian monitoring projects.

Patten (1998) provides reviews and evaluations of the various GCES projects that attempted to integrate factors and functioning of the riverine ecosystem. Using information from this evaluation, recommendations were made regarding methodologies for long-term monitoring and research and a conceptual model of the interrelationships among abiotic and biotic components of the CRE was designed. This model was to aid in designing long-term monitoring.

Patten (1998) acknowledges that a critical step in designing a monitoring program is the selection of indicators that are responsive to environmental stressors. He states that in designing a LTMP, “it is necessary to scientifically identify those riverine attributes that will give the best evidence of changes, or trends in response of dam management scenarios.” He found that the approach used for developing attributes under the Glen Canyon Dam EIS (USDI BOR 1995) resulted in an over-extensive list of attributes that should be measured for monitoring. To reduce the number of attributes (i.e., riverine ecosystem parameters), he ranked each attribute based on how directly it is affected by the management activity (e.g., flood flows), and how sensitive it is to the altered environment. (Endangered species were not included in the rankings because policies required monitoring of these species, thus they were not part of a selection process.) Attributes with the lowest rankings "should be considered prime candidates for monitoring" (Patten 1998). We further summarized the results of Patten's ranking to get an overall sensitivity ranking for each riverine ecosystem parameter (Table 1) to management actions including fluctuations within EIS (ROD), floods <31,000 cfs, floods > 40,000 cfs, temperature control, fish management, and recreation management. Out of 25 individual parameters, birds ranked 21^{st} (tied with mammals). Only two parameters ranked lower in their sensitivity to dam operations parameters and river use management activities. When only riparian terrestrial attributes are considered, Marsh Area is the most sensitive attribute; vegetation canopy cover and plant species diversity are also ranked as slightly more sensitive than birds (Table 2).

To aid further prioritization of the list of attributes for monitoring, in order to reduce the impacts of researchers and monitoring scientists, and ultimately have a more efficient, effective monitoring program, Patten (1998) also examined linkages among attributes and impacts between factors by developing a conceptual model in the form of a matrix. He ranked the "strength" of the relationships (i.e., how much a change in one will influence the value of the other); attributes within the matrix table that received the most ones and twos were "attributes that relate to many processes and thus can be considered integrators of the riverine system." We summed the scores for each attribute to get an overall score that reflects the degree of interaction (i.e., linkage) of each individual attribute with all other attributes (Table 3). Birds had the weakest degree of interaction with other attributes, indicating that they are not strong integrators of the CRE. Thus, considering the rankings of the attributes from each table, hydrological and aquatic parameters ranked higher (i.e., these are most directly affected by dam management activity and are more sensitive to environmental changes) than terrestrial parameters, and birds are among the attributes that are the least sensitive to management activities, and the least responsive to changes in other attributes.

Patten (1998) also reviewed and evaluated the various projects that attempted to integrate factors and functioning of the riverine ecosystem, including the GCES vegetation studies conducted with the avifauna studies. (Sogge et al. (1998) was not yet completed and not included). He found that, unfortunately, these vegetation studies emphasized vegetation as habitat, rather than vegetation as a responder to river flows. Total vegetation volume (TVV) was useful for comparing relative measures of riparian vegetation and avifauna, but it did not provide quantitative information for long-term monitoring of riparian vegetation. The avifauna studies did not provide data on plant communities used by birds; most of the avifaunal surveys only briefly described the vegetation within which detections were made. Thus, information on avian/vegetation-structure relationships that could be used as a model to evaluate future changes in the riparian vegetation along the river, were lacking. This made it difficult to develop response models relating changes in riparian vegetation to changes in the avifauna populations within the canyon (Patten 1998).

Nevertheless, using information from his evaluation of GCES studies, Patten (1998) developed a conceptual model of the interrelationships among abiotic and biotic components of the CRE to aid in designing long-term monitoring. This model reflects the fact that birds are relatively insensitive to dam operations in that they are located at the bottom of the flow chart, with intermediate parameters such as riparian and marsh vegetation, aquatic food base, and shoreline habitat being more directly affected by dam operations, and ultimately affecting riparian birds. Therefore, avian parameters measured by monitoring are less likely to provide insights to the ecological consequences of dam operations, than are vegetation and aquatic parameters.

Estimation of the status and trend of avian indicators/Establishment of sample design

The Strategic Plan identified indicators and information needs for monitoring, called for the development of conceptual models to further refine monitoring priorities, and proposed further studies of monitoring methods that would enable the detection of trends and yield meaningful information for adaptive management. Subsequently, Patten (1998) identified stressors and disturbances, and developed conceptual models linking stressors and ecological responses. These documents were meant to guide subsequent monitoring programs under the auspices of the GCMRC. Instead, avian monitoring projects under the GCMRC were initiated before the long-term monitoring design was completed, and before results of previous studies had been assessed and incorporated into the monitoring program. In particular, a project to establish long-term monitoring of the breeding bird community in the riparian vegetation of the CRE was initiated in 1996 (Petterson and Spence 1997, Spence 1997), prior to completion of the Strategic Plan in 1997 and the conceptual models in 1998. Its objectives were to: 1) describe and compare the breeding bird community from Glen Canyon Dam to the lower Grand Canyon in upper lake Mead (i.e., a continuation of previous surveys), 2) quantify and compare point count surveys and total count walking surveys in terms of: species richness, community composition, and relative species abundance (repeating the comparisons previously conducted by Sogge et al. but not yet published), 3) define feasible monitoring objectives based on species' abundances and sample size considerations, and 4) make recommendations on monitoring techniques suited for long-term avian monitoring along the Colorado River.

This Petterson and Spence project was a continuation of previous bird studies, and was designed using some of the same methods as those developed prior to the development of the Strategic Plan by Sogge et al. (1994), and Grahame and Pinnock (1994, 1995). Because it was initiated prior to the identification of information needs in the Strategic Plan, and prior to development of any conceptual models, this project, which formed the basis for the monitoring work that has been conducted since, assumed the main goal of long-term monitoring was to detect population trends in terrestrial avian populations. It was not designed to examine the potential links between dam operations, riparian habitat, and the breeding bird community. It also did not build upon the findings of Sogge et al. (1998), who recommended indirectly monitoring terrestrial birds by monitoring riparian habitat. However, by comparing survey methods and making recommendations on monitoring techniques for long-term avian monitoring in the CRE, this study did address one of the critical design components, the estimation of the status and trend of avian indicators/establishment of sample design.

As is true for many studies within the CRE, due to logistical constraints sampling sites were non-randomly selected and likely represent biased samples. In Glen Canyon, patches of "suitable" vegetation were subjectively chosen. An additional 42 areas below Glen Canyon, between Lee's Ferry and river mile 265L, were also selected (Petterson and Spence 1997). The criteria for selecting these sites are not described, but many were riparian habitat patches selected for previous GCES bird studies and had been picked to form a representative sample of riparian habitats along the length of the river (Sogge et al. 1998). Also, some sites from previous studies were selected based on the fact that they were larger patches and expected to have more bird species and individuals, so that patch selection was biased towards larger patches with more vegetation volume. Very few of the patches coincided with those of a concurrent study of riparian vegetation. Within selected patches, most point count stations were non-randomly situated halfway between the river and upland desert scrub habitat (Petterson and Spence 1997). Point count data were then compared to data collected from walking surveys through the same patches.

The results of the Petterson and Spence study included recommended sampling designs for future avian monitoring. They found that point counts provide a better index of abundance than walking surveys because point counts have fewer sources of variability and a greater degree of standardization and repeatability can be achieved. Yet, they determined that walking surveys were better at characterizing species richness (i.e., the total number of bird species) in a patch. A ten-minute point count was recommended (Petterson and Spence 1997).

The Petterson and Spence study also attempted to estimate the status and trend of avian indicators in order to make recommendations for long-term monitoring. They cautioned that their analysis was based on small sample size, but reported that the point count sampling scheme used (i.e., three surveys per breeding season that each sampled >100 point count stations) provided sufficient sample sizes to permit detection of relatively large population trend projections of 20% per year for the 13 most common riparian bird species in the CRE (Petterson and Spence 1997).

This study also collected a limited amount of data on floristic composition and abundance, but failed to analyze it. They did recommend that a program to monitor changes in the old high water zone (OHWZ) and new high water zone (NHWZ) vegetation structural components (i.e., canopy cover, patch area, vegetation height, canopy structure) be established in order to link changes in breeding riparian avifauna with the operations of GCD (Petterson and Spence 1997).

In 1998 a project that incorporated the initial 1996 study design and methodology was undertaken to continue baseline monitoring of the breeding riparian avifauna, the Southwestern Willow Flycatcher (SWIFL), and riparian habitat in selected patches along the river corridor (Spence et al. 1998, Spence et al. 1999). (It also studied the winter terrestrial bird community, which is not addressed in this assessment). The final report for this program is currently in preparation (J. Spence, pers. comm.), while a draft of the final report (Spence 2004) was made available for this assessment.

The principle goals for this project differed somewhat from the original 1996-1997 project and were clearly defined in the draft final report (Spence 2004); seven are applicable to this assessment:

1. Conduct baseline monitoring studies on the riparian breeding birds along the river corridor;
2. Develop a monitoring protocol for breeding birds that combines objective methods with repeatable results that can be efficiently implemented under the difficult logistical constraints of the river corridor;
3. Determine the statistical power of the monitoring program to detect change;
4. Develop a habitat monitoring program that links avifauna dynamics with habitat dynamics resulting from potential effects of dam operations;

5. Compare principle results of the breeding bird program with earlier work conducted along the river corridor;
6. Develop specific monitoring criteria (threshold values) that can be directed towards adaptive management goals of the long-term science program;
7. Make long-term recommendations of the feasibility of bird monitoring in detecting ecosystem-wide changes along the river corridor as a result of dam operations.

Considering the goals listed above, this project was designed to address most of the criteria for designing an effective monitoring program (see Part 1). It assumed the general goal of monitoring long-term population trends and riparian breeding birds as identified in the Strategic Plan, and also measured riparian vegetation. Although, significantly, it did not measure the areas of the riparian patches sampled, which had previously been found to explain the majority of variation in bird species richness and density (Sogge et al. 1998) and was identified as a Critical Attribute in the Strategic Plan. Characterization of stressors and disturbances, and development of conceptual models was not done as part of the design of this project, although these were included in the final report. This project does contribute significantly to the GCMRC's information needs in that it tests sampling methods and analyzes the ability to estimate the status and trends of the riparian avifauna using the previously established sampling design, and makes recommendation for monitoring based on these analyses. This information was then used to propose new monitoring protocols (Spence 2004). The development of specific monitoring criteria (threshold values), as listed under item 6 above, was not included in the available draft (Spence 2004).

The Spence project continued baseline monitoring initiated during the 1996-1997 project, using essentially the same study sites and methods. These data were then used to determine the statistical power of the monitoring to detect change, as was done with fewer data by Petterson and Spence (1997). Sample size considerations, sampling protocols and duration of data sampling were examined (Spence 2004). The power analysis showed that data collected by sampling three times during the breeding season, sampling 46 riparian habitat patches over 10 years, considering the 16 most common species, had the power to detect a change of 10% per year in detection rates (i.e., relative abundance) for eight species: Lucy's Warbler (*Vermivora lucia*), House Finch (*Carpodacus mexicanus*), Bell's Vireo (*Vireo bellii*), Bewick's Wren (*Thryomanes bewickii*), Black-chinned Hummingbird (*Archilochus alexandri*), Ash-throated Flycatcher (*Myiarchus cinerascens*), Yellow-breasted Chat (*Icteria virens*), and Blue-gray Gnatcatcher (*Polioptila caerulea*). These species represent approximately 25% of the riparian species and over 80% of the individuals. The variance in the data made it difficult to detect changes of less than 10% per year, while a much larger change of 20% was detectable for Common Yellow-throat, Yellow Warbler (*Dendroica petechia*), and possibly the Song Sparrow (*Melospiza melodia*).

The number of sampling years required to detect a 10% change ranged from 5 to 30 years. Only the Lucy's Warbler would require the minimum 5 years; Bewick's Wren, Bell's Vireo, and Black-chinned Hummingbird require 6-8 years, while the Ash-throated Flycatcher, Yellow-breasted Chat, and Blue-gray Gnatcatcher require 9-10 years. The other eight of the 16 most common species included in the analysis would require over 10 years of monitoring to detect a 10% change; the Brown-headed Cowbird (*Molothrus ater*) requires 30 years. Five of the 16 most commonly detected species cannot be monitored using the sampling protocols tested in the analyses. To adequately monitor these species, monitoring methods would have to be modified by either increasing the number of patches surveyed, increasing the number of surveys per breeding season, grouping species, or relaxing the statistical criteria (see Spence 2004). Even then, there are some species that are relatively rarely detected during point counts, and cannot be effectively monitored using point count methods, if at all. In sum, these analyses showed that the power to detect change in less than 10 years existed for only a few species; 11 species could potentially be monitored for trends ranging from 10-20% but this monitoring would require substantial time commitment (Spence 2004).

In contrast, power analysis of the data from habitat sampling using total vegetation volume (TVV) found it had the power to detect relatively small changes in vegetation volume; a change of 10% TVV could be detected in as little as 5 years (Spence 2004).

Based on power analysis of the bird data, the draft final report (Spence 2004) suggests several changes to the avian monitoring protocols in order to increase the power of the monitoring program to detect changes in breeding bird populations. These, in brief, are:

1. Increase the number of survey trips (i.e., more than three per breeding season).
2. Increase the number of patches surveyed per trip beyond the 45-60 surveyed during this study.
3. Group species by guild, thereby combining detections of several species into one detection rate.
4. Use a different index of abundance (e.g., highest counts for individual species averaged across the years, rather than mean detection rate averaged over sampling years).
5. Select a larger effect size (e.g., 10-20% change in detections).
6. Conducting monitoring for 10-15 years or more.
7. Test data for declines only (i.e., use a one-tailed test for trend analysis).

The first two suggestions would require logistical modifications. Spence (2004) discusses the advantages and disadvantages of the rest. In particular he suggests that lumping species into ecological guilds or indicator guilds (i.e., combining detections of several species into one detection rate), can increase the power of the program to detect change. But, although members of a guild may use the environment similarly, they do not respond similarly to environmental stressors (Mannan et al. 1984, Szaro 1986, Paige 1990, Hutto and Young 2002). Therefore, it is inadvisable to use summary statistics such as species diversity or guild totals as response variables just so rare species can be included in the data analysis (Hutto and Young 2002), or to increase sample sizes.

Bird sampling techniques were also compared. The point count methods used in all but the final year of this project belong to a class of techniques termed index-counting procedures; they have methods that use counts or maps of bird detections as an index to relative abundance. A second type of counting method, which includes Distance Sampling, involves empirical modeling techniques that estimate bird density (Rosenstock et al. 2002). Index counts tally bird detections during one or more surveys of points, transects, or defined areas (Bibby et al. 1992, Ralph et al. 1995), while Distance Sampling was developed with the recognition that some birds are missed during sampling, making it necessary to incorporate some method of figuring out how many birds are missed. Thus, Distance Sampling uses field procedures that are similar to index counts, but have an analytic component that models variation in species' detectability to yield direct estimates of density.

At the time the Spence (2004) project was originally designed, counting techniques that used detectability-based density estimates had not been widely used in bird monitoring. Recently, the biases and limitations of index-counting procedures have undergone extensive debate. Some avian ecologists have proposed that detectability-based techniques such as Distance Sampling deserve wider application (e.g., Fancy and Sauer 2000, Rosenstock et al. 2002). Thus, data were collected in the final field season, and analysis was conducted to assess the feasibility of using Distance sampling techniques to monitor the CRE riparian avifauna.

The results of this study are discussed in the draft final report (Holmes and Spence *in* Spence 2004). Using distance sampling requires that critical assumptions be met that may be problematic given the ecology of the CRE, and the logistical challenges of monitoring in the CRE. One requirement is that the data collected are distances from a *randomly* placed line or point to objects of interest (i.e., the individual bird). Also, when establishing sampling points, consideration must be given to possible gradients in density. So spatial stratification of the study area should be considered (Buckland et al. 1993). Along the Colorado River in the Grand Canyon there are likely gradients in densities for many of the bird species. For example, densities of many species likely change from the upper reaches of the river to the lower reaches and also within patches from the rivers edge through the OHWZ. Also, detection probability often varies with topography, habitat type and density of the objects of interest. Furthermore, and perhaps most importantly, if more than one observer is used, the design should allow estimation by individual observer. Proper design can help cope with these realities (Buckland et al. 1993). Nevertheless, ensuring that adequate sample sizes are obtained for each layer of stratification within the CRE would likely be a monumental task.

Finally, in addition to conducting power analyses and assessing the feasibility of sampling techniques, Spence (2004), a posteriori, identified stressors and disturbances within the CRE, with Dam operations as a primary driver. Six broadly categorized stressors were identified, three of which can be linked to dam operations: study area recreation, breeding habitat (vegetation) dynamics, and dam releases. A preliminary, simple conceptual model was also developed linking these to three broad indicator groups: breeding bird abundance, resource base (seeds, fruits, and insects), and habitat structure. Though the conceptual model was developed after the study was conducted and is extremely simplified, it helps to illustrate that breeding bird abundance within the CRE is affected by numerous other variables outside the CRE and that dam operations can be expected to affect birds primarily through effects on breeding habitat and impacts to recreation. Spence (2004) concludes that more detailed conceptual models should be developed. He further states, "under normal ROD operations, impacts from dam operations are likely to be fairly minor compared with climate and habitat changes outside the Colorado River corridor." He suggests that the major impacts of dam operations are the planned and unplanned floods that can scour out much of the riparian vegetation in the CRE.

Summary of the results of the evaluation

The ultimate success or failure of a monitoring program may be determined by the selection of indicators for monitoring (Noon et al. 1999), making the steps used to make this selection critical. These steps should consist of the definition of goals and objectives, the characterization of stressors and disturbances within the system, and the development of conceptual models that link these stressors to ecological responses.

The GCMRC's long-term monitoring program goals and information needs were defined in the 1997 Strategic Plan. They are to evaluate short-and long-term impacts of the Glen Canyon Dam on the biological, cultural, and physical resources of the CRE and to provide information concerning resources of the CRE specified by AMWG and the Secretary of the Interior. Thus, the GCMRC's long-term monitoring is meant to provide information on the effects of dam operations by measuring selected parameters within the CRE. Key steps for selecting parameters for modeling are the identification of the stressors of the CRE and the potential ecological responses to dam operations. Unfortunately, in developing the 1997 Strategic Plan, these crucial steps were skipped, indicators for monitoring were selected (including riparian birds), and subsequent monitoring projects grew out of this.

The synthesis of information regarding the CRE, the characterization of its stressors and ecological responses, and the linking of these through the development of conceptual models, were completed, after the fact, by Patten (1998). This analysis found that birds are relatively insensitive to dam operations and that avian parameters, as measured in past studies, are less likely to provide insights to the ecological consequences of dam operations than are hydrological, aquatic, and vegetation parameters.

In the same year (1998), the final report of the avian project conducted by Sogge et al. was completed. It is unfortunate that Patten (1998) was unable to include this study in his integration and analysis of GCES research findings, as it provides much of the pertinent information available on the riparian breeding bird community and habitat associations in the CRE (see Part 2).

Nevertheless, Patten's report provided valuable information for designing an integrated monitoring program for the CRE. Unfortunately, it was not referred to during the selection of indicators to monitor, nor was the information incorporated in designing the long-term avian monitoring projects conducted by Petterson and Spence from 1996-1997, and Spence et al. from 1998-2000. This was likely due to the timing of the long-term avian monitoring projects, which were initiated prior to the finalization of the Strategic

Plan, prior to the synthesis and recommendations of Patten (1998), and prior to the completion of Sogge et al. (1998). It is arguable that the design and initiation of the long-term avian monitoring projects should not have been conducted prior to the completion of the Strategic Plan and the analyses conducted by Patten (1998), which were recognized in the Strategic Plan as essential to designing long-term monitoring programs. The findings in Sogge et al. (1998) should have also been considered in the study design of the subsequent avian monitoring programs, including the development of hypotheses for testing, and the selection of habitat parameters to be measured.

As a result of the premature design and initiation of the 1996 to 2000 avian monitoring, these projects were designed to assess the feasibility of monitoring long-term population trends of riparian birds. They were not designed to monitor the effects of dam operations on the riparian avifauna. They did not measure parameters, identified by previous studies, that explain much of the variability in bird species richness and abundance, and potentially link changes in riparian bird abundance to dam operations (e.g., changes in riparian vegetation patch area and composition, changes in marsh vegetation, changes in aquatic insect abundance and composition; Patten 1998, Sogge et al. 1998).

Consequently, the 1996 to 2000 avian monitoring projects have not provided information that enables prediction of how changes in dam operations may affect the abundance and availability of ecological resources that may affect bird species and assemblages. For example, TVV was selected as the main vegetation parameter for monitoring in these studies and it is correlated with bird species richness and abundance (Sogge et al. 1998, Spence 2004). It was not selected based on its sensitivity to dam operations and its ability to link habitat changes due to dam operations with changes in bird species abundance.

Nevertheless, the avian monitoring project, as designed, has provided useful information regarding the feasibility of conducting long-term monitoring of avian populations to detect trends in abundance. It was found that the monitoring program conducted from 1996 to 2000 lacked sufficient power to detect trends in all but the most common riparian species, and that adequately monitoring breeding birds in the CRE would require both substantial resources on a yearly basis and a long-term, multi-year commitment (Spence 2004).

In sum, the original avian GCES studies, the Strategic Plan, the synthesis and information integration by Patten (1998), and the various bird studies that have been conducted since, have provided information to meet the criteria for designing an effective avian monitoring program. Unfortunately, the haphazard, non-sequential manner in which this information was produced has severely limited the efficiency of the process. Each successive project would have benefited from proper planning that included using information provided by past studies regarding the factors believed to affect the dynamics of the ecosystem to develop hypotheses for testing these assumptions. Nevertheless, these projects have provided considerable information about the CRE in general, and the terrestrial avian community ecology. It is appropriate, at this time, to use this information to attempt to meet the criteria for, and take steps to design, an effective monitoring program.

PART 3: DESIGN FOR AN EFFECTIVE AVIAN MONITORING PROGRAM

Using available information to meet the criteria for designing a monitoring program

Our assessment has found that considerable information regarding the terrestrial ecosystem of the CRE exists. Yet it has not been applied in the design of effective long-term monitoring programs in the CRE. Therefore, we utilized this information in meeting the initial criteria for designing an effective monitoring program, and in developing recommendations for future avian monitoring in the CRE.

First, the overall goals and information needs of the GCMRC program are to (1) evaluate short-and long-term impacts of the operations of Glen Canyon Dam on the biological, cultural, and physical resources of the CRE, and (2) provide information concerning resources of the CRE specified by AMWG and the Secretary of the Interior (Garrett et al. 1997). In addition, the Biological Resources Program's research and monitoring programs are also intended to develop information about the structure and function of the CRE (Garrett et al. 1997). The Strategic Plan also calls for integrating parameters for monitoring, thereby addressing relationships between the biotic and abiotic components of the CRE to predict impacts on critical biological resources.

If the first goal is still of primary importance to the GCMRC, and underlies decisionmaking within the AMWG, then it may be time for the GCMRC to reassess its selection of avian parameters for monitoring under the Strategic Plan. As we discussed under Part 2, above, Patten (1998) found that, when compared with other terrestrial parameters, the terrestrial riparian bird community was a relatively insensitive indicator of the effects of dam operations on the terrestrial ecosystem. Subsequent studies (i.e., Sogge et al. 1998, Spence 2004) have born this out. Alternatively, if learning more about the structure and function of the CRE is still a priority, a well-designed monitoring and research program that examines the linkages between riparian vegetation parameters and terrestrial birds, and that monitors changes in these parameters, could provide considerable information about the ecosystem.

Previous avian projects have made substantial contributions to meeting the second goal, providing information on the structure, and to a lesser degree the function, of the terrestrial avifauna community. Yet, these studies have not been adequately addressed the first goal--that of monitoring the impacts of dam operations on the terrestrial ecosystem. Therefore, in suggesting a design for monitoring, we focused on potential effects of dam operations on riparian vegetation and terrestrial birds. Using information gained from our assessment regarding terrestrial ecosystem components within the CRE, we conducted initial steps in the design--characterizing the stressors and disturbances within the CRE associated with dam operations (i.e., differing flow regimes).

Dam operations can affect the terrestrial bird community directly and indirectly. Direct, short-term effects include the flooding of low-lying bird nests during the breeding season, which can be expected to affect a limited number of specific species. The main indirect influences on bird species abundance and richness within a riparian patch are the TVV, the area of riparian vegetation within the patch, the area of tamarisk and mesquite, and geomorphic parameters (Sogge et al. 1998, Spence 2004). Thus, stressors related to dam operations that can be expected to affect the terrestrial bird community are likely those that affect these parameters. The hydrograph (i.e., flow characteristics) has been found to be the most important driving variable, or major stressor, in terrestrial riparian systems (Malanson 1993, Kearsley and Ayers 2001). Kearsley and Ayers (2001) reviewed and summarized the information on the effects of the hydrograph on the terrestrial vegetation of the CRE. From this, we compiled a list of stressors that have occurred as a result of dam operations (Table 4) and their effects on riparian vegetation, as described by Kearsley and Ayers (2001).

We used this information, and information from Sogge et al. (1998) and Spence (2004), to construct a conceptual model that characterizes stressors and their anticipated effects on the ecosystem and its components, based on what is currently known regarding linkages among dam operations, riparian vegetation, and terrestrial avifauna. The resulting conceptual model depicts the vegetative responses of the various hydrograph periods/flow regimes that have been measured by previous studies (enclosed by a rectangle), and linkages of these to both hypothesized (enclosed in a circle) and measured bird responses (enclosed by a rectangle). The arrows indicate linked responses (Figure 1).

We then used the resulting conceptual model (Figure 1) to form the basis for selecting indicators for monitoring and designing an avian monitoring program (Noon et al. 1999). The linking, pathway arrows without question marks are those where responses can be predicted with relatively high probability, based on previous studies. The linking arrows with embedded question marks signify hypothesized ecological responses, and thus identify information gaps and areas for further study.

The hydrograph during the high flow era resulted in stimulation of germination and early growth for most plant species, including tamarisk and OHWZ plants (especially mesquite), an increase in tamarisk in cobblebars, removal of tamarisk from silt and sand terraces, and loss of herbaceous vegetation in marshes (Stevens and Waring 1985, Kearsley and Ayers 2001). The long-term effects of sustained high flows on riparian vegetation are unclear. If increased germination and early growth compensate for the loss of tamarisk from silt and sand bars, and lead to increases in the area of mesquite and or/riparian patch size, these can be expected to increase bird species abundance and bird species richness for the patch. Conversely, the loss of marsh vegetation can be expected to result in a decrease or loss of bird species that depend on the presence of this habitat type, almost exclusively the Common Yellowthroat.

The high flows were not sustained, and during the recovery era wetland patches returned to areas where they had been removed or buried, and NHWZ vegetation increased towards previous levels (Kearsley and Ayers 2001). Sufficient data existed for one bird species (Bell's Vireo), of the new and old high water zones, to determine that its numbers recovered to pre-high-flow levels (Brown 1988).

During the next hydrographic period, the interim flow era, riparian vegetation expanded into areas exposed due to reduced maximum discharges, NHWZ vegetation increased, and the reduction in river stage caused a drawdown of groundwater. Concomitantly, there was a shift to more upland plant species in nearly all habitats, a loss of moisture loving species, and willows at higher elevations experienced reduced annual stem growth (Stevens and Ayers 1993, Kearsley and Ayers 2001). Inundation frequency (determined by the elevation of the riparian plants) and geomorphic setting, were found by Stevens and Ayers (1993) to be the primary determinants of vegetation composition and productivity in the river corridor. Also, low elevation areas of return current channels trapped fine sediments and fostered the development of wetland vegetation (Kearsley and Ayers 2001). From these observations we predict that if interim flows persisted, there would be an increase in NHWZ vegetation in newly exposed areas. Yet, this gain may be offset by the compositional shifts to more upland plant species and less water-loving species, resulting in no net gain in the area or TVV of NHWZ vegetation. If overall riparian patch area remained unchanged we predict that riparian bird species richness and abundance within the patch would not change. If areas of riparian vegetation converted to areas of upland vegetation, reducing the area of riparian vegetation, we predict a decrease in riparian bird species richness and abundance. Marsh-dependent bird species would likely be maintained in proportion to the amount of available habitat. Changes in plant species composition within a riparian patch do not significantly affect the overall abundance or richness of birds (Sogge et al. 1998), but likely affects the abundance and distribution of specific bird species. Yet, information is lacking on factors affecting individual species' distribution and abundance within the CRE.

The 1996 experimental flood of the Adaptive Management era did not affect woody perennials within riparian patches; area, canopy cover, and TVV of woody perennials are determinants of bird species richness and abundance. Thus, the flood may have affected some individual nests that were inundated, but it likely had negligible effects on the bird community. The steady high flows of this era led to increases in the vegetation density in the lower 2 meters of the canopy at sites lower down the river, but there was no change in total foliar cover of riparian vegetation. Based on past bird studies we predict that there would be no change in bird species abundance and richness resulting from these flows. We cannot predict how an increase in the lower 2 m canopy density would affect the bird community, although we suspect that some species, such as Lucy's Warbler, may increase in response to these changes.

This conceptual model, based on the results of riparian vegetation studies and bird monitoring, exposes how little is known about the relationships between bird species and vegetation parameters, and the longer-term effects of dam operations on patch vegetation and birds. This is due to the limited extent to which these programs integrated terrestrial vegetation and bird monitoring. Vegetation studies conducted in conjunction with bird monitoring did not measure responses of riparian vegetation to dam operations, and vegetation monitoring projects did not track changes in riparian habitat that have been shown to affect the bird community, including TVV and area of vegetation types. The result is that, at this stage, the ability to select indicators for monitoring that track the effects of dam operations on the terrestrial ecosystem is extremely limited (as indicated by the many question marks in the model).

To select appropriate indicators, better information is needed that links the effect of dam operations to measurable aspects of structural and compositional habitat components that affect bird species. This includes determining what constitutes a resource for birds on a species-specific basis, and the factors that affect the abundance, availability, and use of that resource. The limited ability to identify these linkages using the information provided by the avian monitoring projects (e.g., Sogge et al. 1998, Spence et al. 1999) is largely due to their usage of community-level measures of avian populations, including bird species richness (the number of species), abundance (the number of individuals), and diversity indices, as their response variables. Species do not respond similarly to environmental influences (Mannan et al. 1984, Szaro 1986, Paige 1990) and interpretation of community-level patterns such as these requires looking at changes in each individual species and determining how these changes affect the community-level diversity values (Wiens 1989, Morrison et al. 1992, Sogge et al. 1998).

Thus, measuring the responses of specific species, and examining patterns in these responses across species can achieve a clearer picture of the effects of habitat changes. In addition, specific species should be monitored because a monitoring program that tracks populations of species assemblages, without measuring populations of specific species, may mask trends affecting individual species and the response of rare species will be statistically swamped by the more common ones (Hutto 1989, Baker and Lacki 1997, Hutto and Young 2002). Therefore, community-level metrics will be ineffective and even misleading if used as monitoring tools (Hutto and Young 2002) and, in the situation where the population of one species is declining, this represents a potentially large risk (Block et al. 1995).

In order to better understand linkages between avian populations, vegetation/habitat parameters, and dam operations, we suggest that studies are needed on what constitutes a resource on species-specific basis, and the factors and processes that may affect a bird species and its resources (Wiens 1989). For example, the relationships between the more common individual birds species and TVV, patch size, area of OHWZ and NHWZ vegetation should be modeled. This would aid in the determination of appropriate response variables/indicators to measure and monitor in order to make inferences about the effects of management actions/disturbance events on birds in the CRE. Much, perhaps all, of this could be accomplished with existing data, without new fieldwork.

In addition to using the above methods for selecting indicators, species that are found to be declining, and thus are of conservation concern at multiple spatial scales (i.e., both within and outside the CRE) can also be appropriate indicators for monitoring in the CRE (if they can be reliably monitored). Clearly defining population trends allows for identification of species attributes and/or environmental conditions associated with the susceptibility of populations to decline. For example, mechanistic AMMP studies could be designed and conducted to gain insight into the causes behind measured population level differences (Hutto and Young 2002).

Population trends are likely a result of factors working at multiple spatial scales. Comparing the patterns of these trends across spatial scales helps to determine if the trends are due to local perturbations/disturbances within the canyon, or are likely the result of factors occurring at larger scales, beyond the confines of the canyon. Thus, in order to assess which species found within the CRE are of concern at a local, state-wide, regional, and national scale, we incorporated the canyon-wide trend information for the 16 most common species reported by Spence (2004) with trend information from different spatial and temporal scales using Breeding Bird Survey trend results for the period from 1996 to 2002 and 1983 to 2001 (Table 5; Sauer et al. 2003). It should be noted that, although the BBS provides a large amount of information about regional population change for many species, there are a variety of possible problems with estimates of population change from BBS data. Small sample sizes, low relative abundances on survey routes, imprecise trends, and missing data all can compromise BBS results (Sauer et al. 2003). Therefore, we use these trends only as a tool for assessing patterns of trends within species, and identifying species that may warrant further study and/or monitoring.

Data on the terrestrial avifauna of the CRE have limited power to detect trends, yet when examined at the local, CRE scale, the Blue-gray Gnatcatcher and Ash-throated Flycatcher showed consistent declining trends (Spence 2004). In contrast, BBS data analyzed at the statewide, Arizona-Colorado-New Mexico-Utah, Western Region, and National Scales, show increasing trends for both the gnatcatcher and the Ash throated Flycatcher (Table 5). This pattern may indicate that there are unique environmental conditions associated with the susceptibility of populations of these species to decline within the CRE. It may also mean that there is no strong reason to be concerned about these species and they should not drive management actions. Further information regarding their habitat requirements and ecology within the CRE could provide insight into the causes of these apparent differences. For example, are Blue-gray Gnatcatchers restricted to nesting and/or foraging in OHWZ vegetation? If so, has the availability of this habitat changed, and are these habitats affected by dam operations over the long-term?

The Lesser Goldfinch (*Carduelis psaltria*) illustrates the value in looking at trends at multiple scales, and considering the natural history of the species when interpreting patterns. The Lesser Goldfinch has apparently declined in the CRE (Spence 2004), but has concomitantly shown increases in Arizona and the surrounding states from 1983-2002 (Sauer et al. 2003). Spence (2004) found that, in particular, there was a strong decline in detection rates in the Grand Canyon since 1998. During this same time frame (1998-2000), BBS data for both Arizona and the Arizona-Colorado-New Mexico-Utah region show declines from 1998- 2000 (though not statistically significant). In contrast, the Western Region had slight, non-significant, increases during the same time period. The Lesser Goldfinch is often nomadic and sporadic in occurrence (Watt and Willoughby 1999). Thus, measured "declines" in an area such as the CRE may actually reflect a large-scale movement out of the area, rather than an actual decline in the population.

The benefit of considering patterns over multiple scales is also illustrated by Yellow Warbler and Bullock's Oriole; both showed increases in the CRE. The Yellow Warbler has shown increases across all scales (Table 5), indicating that factors associated with these increases are likely working at multiple or large spatial scales. The Bullock's Oriole, on the other hand, has shown declines (some significant) at all larger spatial scales.

When the sixteen most common riparian bird species in the CRE are examined, half have shown statistically insignificant declines in Arizona; five of these eight also show declines in the Arizona-Colorado-New Mexico-Utah region. Only two species, the House Finch and the Lesser Goldfinch showed a different direction in trends between Arizona and the Western Region (Table 5). These patterns suggest that factors affecting populations of these species may be acting at scales larger than the CRE.

As discussed above, there are limitations to the application of BBS data, and basing decisions such as the selection of indicators for monitoring on trend data alone is not advised. Recently, Partners in Flight (PIF), a voluntary, international coalition of government agencies, conservation groups, academic institutions, private businesses and citizens, has employed other criteria for determining bird species most in need of conservation. It developed geographically based Bird Conservation Plans that prioritize bird species and habitats that warrant conservation action. In the PIF prioritization process, bird species are scored according to their abundance, their distribution, and the level of threats to the species and its habitat (see Table 6). The scores of each component are then summed to give an overall score for the species. All species within a Bird Conservation Region are then ranked from highest priority to lesser. By combining information on relative abundance, threats, and the relative distribution of species (i.e., whether it is restricted to a relatively small geographic area), the information provided by the PIF Bird Conservation Plan that pertains to the CRE is useful in identifying species of concern within the CRE that may be appropriate candidates for monitoring.

The Bird Conservation Plan that pertains to the CRE is the Arizona Bird Conservation Plan (Latta et al. 1999) and its scores for the most common terrestrial riparian bird species in the CRE are shown in Table 6. Although the highest priority species within the CRE, Lucy's Warbler, is relatively abundant in appropriate habitat, it scored high because it has a limited breeding distribution and lives in a highly threatened habitat, lowland riparian vegetation. In addition, Lucy's Warblers are apparently decreasing at every scale of BBS data analyzed (Table 5). Within the CRE, Spence (2004) shows Lucy's Warbler numbers increasing until 1998 then decreasing. This pattern holds for most of the other riparian-dependent species in the CRE. This may be due to methodologies (i.e., a change in observers), but it is interesting to note that 1998 marked the first year of the current drought. Perhaps most importantly, for the top two species in Table 6 (Lucy's Warbler, and the *arizonae* subspecies of the Bell's Vireo), Arizona represents 51-100% of these species' total breeding distribution, much of which is within the CRE. These factors suggest that these species may be good candidates for further monitoring. Yet, monitoring for even these common species would require a considerable commitment from the GCMRC: Spence (2004) found good power to detect a 5% trend in Lucy's Warbler after 8 years; for Bell's Vireo, the same trend would be detectable after 10 years.

In sum, this evaluation shows the value of assessing information gained from past terrestrial vegetation and avian monitoring to assist in the identification of indicators for future monitoring. In particular, by assessing past programs and the information they have provided, we identified gaps in the knowledge needed to design an effective long-term avian monitoring program (LTMP). In particular, further information is needed regarding the habitat requirements of the particular species that comprise the CRE avifauna, in order to predict their responses to changes in these resources and to identify bird species that would be good indicators of these changes. With this information, a well-designed LTMP that takes into account sampling design and statistical power (as examined by Spence (2004) can be used to establish baseline values regarding the distribution and abundance of specific species from which future comparisons can be made over time. If this information is linked to information regarding ecological resources and habitat requirements for specific species, and is conducted in conjunction with more regional, large-scale monitoring, it may yield insight into the causes of population changes, and the effects of management actions. This would require a significant commitment of resources in order to provide the information that could be used in effective decision-making within the CRE by the GCMRC and the AMWG.

Recommendations

The GCMRC should evaluate the synthesis of information by Patten (1998), and research and monitoring that has been done to date, including our assessment of the avian monitoring projects. Based on this evaluation, with information on the degree of commitment needed to adequately monitor birds provided by Spence (2004) the GCMRC should reassess its selection of indicators for long-term monitoring in the CRE and select response variables for monitoring that serve as indicators of changes in key resources.

If the GCMRC chooses terrestrial avifauna as indictors for continued monitoring, we suggest that more information is needed on avian/vegetation-structure relationships that can be used as a model to evaluate future changes in the riparian vegetation along the river and relate these changes to changes in terrestrial avifauna populations within the CRE. In particular, the relationships between patch-level habitat variables (e.g., TVV, riparian vegetation patch size, area of NHWZ and OHWZ vegetation types, geomorphology), found to explain total bird species richness and abundance (Sogge et al. 1998, Spence 2004), and the abundance and distribution of specific bird species should be modeled. It should be possible to do this with previously collected data regarding bird species abundance and distribution and data currently being collected on birds and riparian vegetation. Further study into the linkages between vegetation, dam operations, and the bird community is also needed.

Riparian vegetation monitoring should be designed to provide information on the more long-term effects of the hydrograph on vegetation at the patch-level. An effective monitoring program, that tracks changes in patch-level vegetation parameters that have been found to affect the distribution and abundance of terrestrial birds in the CRE (e.g., TVV, riparian vegetation patch size, area of NHWZ and OHWZ vegetation types) should be established. Monitoring should be designed to provide information on the interrelationships between these parameters, and the stressors that affect them. For instance, more information is needed regarding the factors that affect the TVV within a patch, and methodologies that can provide quantitative information for long-term monitoring of riparian vegetation.

Information regarding bird species habitat requirements and changes in riparian vegetation could then be used to refine the conceptual model presented herein. This conceptual model could then be used to further expose interesting habitat association patterns and the effects of dam operations on habitat parameters. This would enable the identification of appropriate indicators. Then mechanistic studies could be designed that provide probable explanations of the effects of dam operations on vegetation parameters and the patterns of distribution and abundance of bird species of concern within the CRE. Better information regarding the interrelationships of bird species and riparian vegetation would also enable the assessment of the capacity of monitoring vegetation changes as a surrogate for monitoring birds, as suggested by Sogge et al. (1998).

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Table 1. Results of summing ranking scores from Patten (1998) Table II-1, Sensitivity of Monitoring Parameters to Dam Operation Parameters and River Use Management Activities. A median value was given to scores that were listed as a range in the original table (e.g. an original score of 1-2 was given a “new” score of 1.5). The Overall Score is the sum of the individual scores given for Dam operations parameters: Fluctuations within EIS (ROD), Floods <31,000 cfs, Floods > 40,000 cfs, Temperature control, Fish management, and Recreation management. Parameters with the lowest scores are the most sensitive.

Riverine Ecosystem Parameters	**Overall Sensitivity to Dam Operations Parameters**
Non-native Fishes	10.5
Native Fishes	11.5
Algae	12
Invertebrates	12.5
Stage Changes	14
Peak Flows	14.5

Suspended Sediments	15
Elevated Deposits	15
X-sections	15
Margin Habitats	15
Water Quality/Dissolved Oxygen	15.5
Bedload	16
Return Current Channels Size	16
Reattach. Bar Elevation	16
Marsh Area	16
Water Quality/Temperature	16.5
Vegetation Canopy %	17
Plant Species Diversity	17
Water Quality/Dissolved Organic Comp.	17.5
Low Flows	17.5
Birds	**18**
Mammals	18
Water Quality/pH	18.5
Reptiles	19.5
Water Quality/Electrical Conductivity	21

Table 2. Sensitivity of Terrestrial Riparian Ecosystem Parameters to Dam Operations. Results of summing ranking scores for riparian parameters only, from Patten (1998) Table II-1, Sensitivity of Monitoring Parameters to Dam Operation Parameters and River Use Management Activities. A median value was given to scores that were listed as a range in the original table (e.g. an original score of 1-2 was given a "new" score of 1.5). The Overall Score is the sum of the individual scores given for Dam operations parameters: Fluctuations within EIS (ROD), Floods <31,000 cfs, Floods > 40,000 cfs, Temperature control, Fish management, and Recreation management. Parameters with the lowest scores are the most sensitive.

Riverine Ecosystem Riparian Parameters	**Overall Sensitivity to Dam Operations Parameters**
Marsh Area	16
Vegetation Canopy %	17
Plant Species Diversity	17
Birds	18
Mammals	18

Reptiles	19.5

Table 3. Degree of interrelatedness among parameters and their sensitivity. Summary of Patten (1998) Table II-2, Sensitivity among monitoring parameters showing strength of interrelationships. Parameters were given scores based on the strength of their interrelationships with 1= directly related, 2= moderately related, 3= indirectly related, 4= unrelated. We summed the individual scores for each parameter to get and overall score for the strength of interrelationships. The lowest scores are the most interrelated and sensitive to dam operations.

Riverine Ecosystem Parameters	**Overall Strength of interrelationships**
suspended sediments	35
peak flows	37
stage changes	37
low flows	38
Return current channel size	41
non-native fishes	42
native fishes	46
algae	47
X-sections	49

bedload	51
aquatic Inverts	52
marsh Area	53
elevated deposits	55
margin habitats	57
water temperature	58
reattachment bar elevation	58
vegetation canopy	58
water electrical conductivity	59
water dissolved organic compounds	59
water dissolved oxygen	60
species diversity	64
water pH	65
birds	**69**

Table 4. List of Stressors of the Colorado River Ecosystem. From Kearsley and Ayers (2001). Includes hydrographs that can be expected to affect the current state of established riparian vegetation.

Stressor/Hydrograph Period	Hydrograph Characteristics
High Flow Impacts (1983-1987)	Sustained high flows. High peak flow in 1983 (3500 cms) and 1984-1987 (1300-1700 cms).
Recovery Era (1987-1991)	Almost no releases above 700 cms (50-700 cms/day).
Interim Flows (1990-1995)	Reduced peak flows (1150 cms) and intraday ranges (200 cms). Test flows in 1990 and 1991.
Adaptive Management (1996-1999)	Similar to interim flows, but with controlled flood (1996) and high steady flows (1997).

Table 5. Trends for the 16 most common riparian bird species in the CRE by region and time period. Trends for the CRE are from Spence (2004); other trends are the results of analyses of Breeding Bird Survey data (Sauer et al. 2003).

SPECIES	CRE	AZ 1966-2002	AZ 1983-2002	AZ,CO,NM, UT 1966-2002	AZ,CO,NM, UT 1983-2002	WESTERN REGION	NATIONAL
Lucy's Warbler		-	-	-	-	-	-
House Finch		-	-	+	+	+	++
Bewick's Wren		+	--	+	--	--	-
Bell's Vireo		-	-	-	-	-	-
Black-chinned Hummingbird		-	-	+	+	-	-
Ash-throated Flycatcher	-	+	+	+	++	++	++
Yellow-breasted Chat		+	++	+	+	+	+
Blue-gray Gnatcatcher	-	+	+	+	+	+	++
Mourning Dove		-	-	-	+	-	++
Blue Grosbeak		+	+	+	+	+	+
Common Yellowthroat		+	+	+	+	+	--
Yellow Warbler	+	++	+	+	+	+	+
Bullock's Oriole	+	+	-	-	--	--	--
Lesser Goldfinch	-	+	+	+	+	-	-
Song Sparrow		+	+	++	+	-	-
Brown-headed Cowbird		--	--	-	--	--	--

+ non-significant increasing trend, $p > 0.05$
++ significant increasing trend, $p < 0.05$
- non-significant decreasing trend, $p > 0.05$
--significant decreasing trend, $p < 0.05$

Table 6. Prioritized list of the most common riparian bird species of the CRE. Based on Partner's in Flight criteria (Latta et al. 1999). Criteria scores of the Relative Abundance and Arizona Abundance range from 1=abundant to 5=very rare; Breeding Distribution and Arizona Breeding Distribution range from 1=very widespread to 5=very local; Rangewide Breeding, Arizona Breeding, and Winter Ground Threats range from 1=no known threat to 5=extirpation likely; Importance of Arizona to Each Species range from 1=very low to 5=very high.

SPECIES	**RA**	**ABA**	**BD**	**ABD**	**TB**	**TBA**	**TW**	**IA**	**Sum**
Lucy's Warbler	2	2	5	3	4	4	4	5	29
Bell's Vireo (*arizonae*)	3	2	3	3	3	3	3	5	25
Yellow-breasted Chat	2	2	2	3	3	3	3	1	19
Bullock's Oriole	2	2	2	2	3	3	3	2	19
Bewick's Wren	2	2	3	2	3	1	3	2	18
Black-chinned Hummingbird	2	2	3	2	2	3	2	2	18
Ashthroated Flycatcher	2	2	3	2	2	2	2	3	18
Lesser Goldfinch	2	2	3	2	2	3	2	2	18
Blue Grosbeak	3	2	2	3	2	2	2	1	17
Blue-gray Gnatcatcher	2	2	2	2	3	2	2	1	16
Common Yellowthroat	1	2	1	3	3	3	2	1	16
Song Sparrow	1	1	1	3	3	4	1	1	15
House Finch	1	1	2	1	1	1	1	2	10
Mourning Dove	1	1	1	1	1	1	1	1	8
Brown-headed Cowbird	1	1	1	1	1	1	1	1	8

RA – Relative Abundance
ABA – Arizona Abundance
BD – Breeding Distribution
ABD- Arizona Breeding Distribution
TB – Threats on Breeding Grounds Rangewide
TBA - Threats on Breeding Grounds in Arizona
TW – Threats on Wintering Grounds
IA – Importance of Arizona to Each Species
Sum = Total of Criteria Scores

Conceptual Model of Glen Canyon Dam Operations' Effects on Riparian Vegetation and Birds

Based on Kearsley and Ayers (2001), Brown (1988), Sogge et al. (1998), and Spence (2004).
Squares signify effects that have been measured; circles represent hypothetical effects.