Revision No. 3

LONG-TERM MONITORING PLAN FOR FISH POPULATIONS IN SELECTED WATERS OF THE GILA RIVER BASIN, ARIZONA

Prepared for

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Individuals too numerous to name from a suite of state and federal agencies, non-governmental organizations, and the private sector have offered constructive comments and suggestions across the years, and these have been liberally incorporated to the betterment of this final document. The plan continues to be a work in progress, and the reader is encouraged to provide feedback that can be used to further improve the long-term monitoring plan for fish populations in selected waters of the Gila River basin, Arizona. Errors herein of omission or fact are the responsibility of the authors.

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INTRODUCTION

The Central Arizona Project (CAP) is a series of aqueducts and pipelines that transports Colorado River water from Lake Havasu, Arizona-California, to central and southern Arizona for agricultural, municipal, and industrial uses. The CAP was authorized by Congress in the Colorado River Basin Project Act of 1968, and construction was largely completed by the U.S. Bureau of Reclamation (Reclamation) in 1993. A U.S. Fish and Wildlife Service (FWS) Biological Opinion (BO) and two revisions on transportation and delivery of CAP water to the Gila River and Santa Cruz River basins (FWS 1994, 2001, 2008) determined that the project would jeopardize the continued existence of five threatened or endangered fishes: Gila topminnow *Poeciliopsis occidentalis*, Gila chub *Gila intermedia*, spikedace *Meda fulgida*, loach minnow *Tiaroga cobitis*, and razorback sucker *Xyrauchen texanus*. FWS (1994) also determined that the project would adversely modify designated critical habitat of the latter four species. The primary justification for the jeopardy opinion was the potential for transfers of nonindigenous fishes and other aquatic organisms from the Lower Colorado River to various drainages in the Gila River Basin via the CAP, where they could negatively impact threatened or endangered fishes.

A Reasonable and Prudent Alternative (RPA) of the BO directed that Reclamation, in cooperation with the Arizona Game and Fish Department (AZGFD) and FWS, "...develop and implement a baseline study and long-term monitoring of the presence and distribution of non-native fish..." in the CAP aqueduct and selected river and canal reaches in Arizona. Monitoring for these purposes includes two broad categories (MacDonald et al. 1991): *baseline monitoring* that characterizes existing conditions and establishes a database for planning or future comparisons; and *trend monitoring* that takes measurements at regular, well-spaced time intervals to determine the long-term trend in a particular parameter or parameters. *Project monitoring* (assessing the impact of a particular project) is also an implied purpose, but it may not always be possible to determine if nonnative fish impacts are the direct result of CAP fish translocations.

Target reaches to be monitored include (1) the CAP aqueduct, (2) Salt River Project (SRP) Arizona (North) and South canals (3) Florence-Casa Grande (FCG) Canal (4) Salt River between Stewart Mountain Dam and Granite Reef Dam, (5) Gila River between Coolidge and Ashurst-Hayden dams, (6) perennial reaches of the San Pedro River downstream from the U.S.-Mexico border, and (7) Cienega Creek between Pantano and Vail. The monitoring program is to persist through the 100-year life of the CAP, or until changes in the formal status of the listed fishes under ESA render the BO unnecessary.

This document presents methodologies considered necessary to “...establish baseline data on the presence and distribution of non-native fishes in the target reaches and to detect changes in the species composition or distribution" (FWS 1994). The plan defines: 1) specific parameters to monitor, 2) repeatable methodologies to collect data on parameters of interest, 3) a standardized database for storage and retrieval of data, and 4) statistical techniques to be applied for data analyses. Appendices provide a comprehensive summary of canal, river and stream sampling locations, standard operating procedure field manual, and data entry guide for use by investigators.

Reclamation intends this document to serve as a guide for contracted and Reclamation investigators conducting monitoring activities to standardize repeatable methodologies and ensure comparability of results. Although basic elements of a management action plan are conceptualized, additional definition of corrective actions and their acceptance by management agencies is required. A management team must be established to implement the management action plan on short notice.

OBJECTIVES

Objective 1) Determine parameters to monitor in target reaches.

The goal of the monitoring plan as stated in the BO is "...to establish baseline data on the presence and distribution of non-native fishes in the target reaches and to detect changes in the species composition or distribution." The ability to detect the presence of a new species in a target reach or drainage (i.e., the ability to determine species richness) is essential to the purpose of the monitoring program. Rapid detection followed by management action is necessary to ensure that impacts of new species on native fishes remain localized and minimal; early detection may be the only opportunity for eradication (Courtenay and Hensley 1980). Collection of a single specimen of a new species should be considered adequate to initiate immediate intensive monitoring, and possibly more extreme management actions.

Determination of the distributions of monitored species is necessary to evaluate geographic extent of invasion impacts, and the potential for further invasion into other drainage areas. This information will aid in planning for possible eradication activities, or for native fish repatriation efforts.

Monitoring of species composition (assemblage structure) is important to evaluate species trends, species interactions, and status of rare species. Knowledge of assemblage structure over time, and cognizance of the natural variation of fish populations (Hall and Knight 1981, Platts and Nelson 1988, House 1995) and their responses to short-term disturbance events and long-term habitat or biological change is the basis for understanding dynamics of the fish assemblage, i.e. its stability, persistence, and resilience (Connell and Sousa 1983, Meffe and Minckley 1987, Grossman et al. 1990).

Also, knowledge of the variation in annual reproductive success of fishes would be of great value in understanding their life history dynamics in the varied habitats to be monitored under this plan. To obtain an index of reproductive success, collected fishes are categorized into a dichotomous age class according to the convention 0 = young-of-year of species that attain relatively large adult body size, and 1+ = typically adult individuals, 1 or more years of age, for fish that attain large body size; fish that remain relatively small throughout life are not aged.

For practical purposes, fish shorter than about 10 cm total length (TL) are considered to represent age-0 and fish longer than 10 cm to represent age-1+. While recognizing that subjective categorization may not always be accurate in the field, especially if multiple-spawns occur within a given year, young-of-year (age-0) is usually the most easily differentiated age class within a multi-aged population. Because all fishes collected within quantitative sampling stations must be enumerated for estimation of assemblage structure, this procedure is not expected to substantively complicate data collection procedures. The opportunity to acquire this long-term data set should not be forgone.

Revision No. 2 of this plan (Clarkson 1996) incorporated detailed measurements of stream mesohabitats to enhance the ability to interpret monitoring data. However, habitat data acquisition procedures proved time-consuming (requiring up to 50% of field time) and their utility for enhancing the goals of the monitoring program were not well-established in the published literature (e.g., Peterson and Rabeni 2001). In addition, a specific evaluation of 1995-1999 data collected under this plan concluded that stratification of fish monitoring data by habitat types (pool, riffle, run) accounted for only about one-third of the total variance of fish counts, and did not improve trend estimates of fish counts (Allison 2001). Although fish captures are tracked according to habitat type, measurement of habitats has been discontinued.

Objective 2) Develop repeatable methodologies to collect data on parameters of interest.

A. Sampling reaches

Native and nonnative fishes respond in different ways to environmental disturbances (e.g., flooding) in different geomorphic reach types (e.g., highly confined canyons vs. poorly confined valleys) (Minckley and Meffe 1987). Thus, stratification of sampling reaches according to geomorphology may facilitate an understanding of the variance of species richness, distribution, and assemblage structure. Classification of Arizona streams in this manner for statistical management of data has been used successfully in White Mountains area trout streams (Clarkson and Wilson 1995) and in the Colorado River in Grand Canyon (Valdez and Ryel 1995). The utility of the stratified design for Gila River basin waters was confirmed by Allison (2000).

Procedures

Streams--A helicopter overflight of stream reaches to be sampled was conducted by Reclamation to validate preliminary reach designations based on stream gradient and channel confinement characteristics determined from U.S. Geological Survey (USGS) topographic maps for Gila and Salt rivers, or on presence of perennial surface water determined from Brown et al. (1981) for the San Pedro River. Reach boundaries are presented in Table 1. This level of stream classification is analogous to the landtype stratum of Lotspeich and Platts (1982) and Nelson et al. (1992), and the channel type of Rosgen (1985).

Canals--CAP canal sampling reaches were delineated according to the established geopolitical divisions representing the Hayden-Rhodes, Fannin-McFarland, and Tucson aqueducts (Table 1). Sampling of SRP canals primarily will be limited to the South Canal between Granite Reef Dam and the junction of the Tempe and Consolidated canals, and the Arizona Canal between Granite Reef Dam and Indian Bend Wash (Table 1). Based on SRP canal system sampling reported by Marsh and Minckley (1982), species diversity diminished considerably downstream from these points, but Wright and Sorensen (1995) found greater numbers of species at the terminus of the Arizona Canal. Other areas of the SRP canal system should be opportunistically sampled where possible. The reach of concern in the FCG canal extends from Ashurst-Hayden Dam to the Pima Lateral canal (Table 1).

B. Sampling stations

To estimate within-reach variance of monitored parameters, two or three systematic sampling stations have been permanently established within each geomorphic stream reach or designated canal reach, where possible (Table 1, Appendix A). A systematic sampling design can substantially reduce data variability, and thus the sample size required to obtain a given level of precision (Hayek 1994). Systematic sampling should also provide a reasonable expectation that stations are representative of the reach (Paulsen and Linthurst 1994), and will ensure a wide spatial distribution of sampling sites. These fixed stations have been used and will continue to be used for long-term temporal and spatial comparisons of fish communities in the monitoring program (e.g. Kesner and Marsh 2010b). Fixed stations are sampled in the same period every year (see *Sampling periodicity* below).

CAP canal stations were located at structural features that facilitate sampling (pumping plant forebays) (Table 1, Appendix A). A single sampling station (Salt-Gila pumping plant) within the Fannin-McFarland portion of the CAP was selected because there is only one pumping plant located in that reach. Because annual dry-up procedures vary from year to year on the SRP canals, no fixed sampling stations were established there except between the electrical fish barriers and Granite Reef Dam on the Arizona and South canals (Table 1). For this reason, sampling below the electrical fish barriers in the SRP canals is opportunistic, varying according to sampling accessibility to structural features that may concentrate fishes. FCG canal sampling also follows this pattern (no fixed sampling stations).

Species occurrence and abundance are influenced by availability of habitats. Thus, to minimize bias of assemblage structure estimates and ensure a representative sample, sampling effort is applied in proportion to the amount of different habitats available. The simplest approach to sample according to proportional allocation is to *a priori* choose a reach length considered adequate to depict a sampling site, and sample every habitat within that reach. To achieve objectives of the FWS Opinion, intensive quantitative sampling over a 200 m reach of stream is used in addition to other qualitative sampling of uncommon habitats in contiguous reaches (see earlier monitoring plan revisions for justification). Data from each 200 m quantitative sample is used to determine assemblage structure of common species, and extensive qualitative samples enhance the ability to determine species richness and presence of rare species. Sampling of 200 m of a stream with a mean width of 5.7 m or less satisfies the minimum length:width ratio=35 criterion of Lyons (1992). Based on Reclamation sampling experiences, intensive sampling of longer reaches does not ensure detection of rare species, and decreases the sampling efficiency of field crews. In a statistical review of 1995-1998 data collected under this plan, Allison (2000) recommended retaining the stratification of three stations per reach.

Procedures

Streams--Systematic station sites were initially identified on USGS topographic maps, overflown by helicopter, and further defined in the field (Table 1, Appendix A). A number of the original sites were those visited as part of the "Fall Fish Count," but that program no longer is in existence. And, since initial designations were made, some sites have changed because of access issues, and others have been deleted from the program. Only stations in active use as of January 1, 2011 are included here. Systematic station locations span most of the reach length and they are approximately equidistant, depending on access points. Downstream station boundaries will be defined using the Global Positioning System (GPS). Upstream station boundaries are 200 stream meters above the downstream boundary, measured along the thalweg with either a tape or hip chain. Upstream and in some cases downstream boundary locations can vary, depending on changes in channel sinuosity over time, and therefore they are not be permanently marked. Random sampling locations will not need permanent markers, but locations will be precisely defined on maps, on the ground using GPS, and described physically. Photo-documentation of upper and lower station boundaries is required.

Canals--Due to logistical difficulties of sampling the deep, high current-velocity habitats characteristic of the CAP aqueduct, sampling stations consist primarily of the forebays immediately upstream from the pumping plants, which are sampled only during canal "outages" when flows are reduced to less than 500 cubic feet per second (Table 1, Appendix A). Opportunistic sampling is necessary on the SRP and FCG canals (Table 1, Appendix A). Precise descriptions of sampling sites should be recorded by Reclamation or contracted investigators.

Procedures

Streams-- Reclamation does not require blocking of station boundaries during sampling. Mesohabitat unit boundaries are identified with temporary flagged stakes. The type name of the habitat unit is recorded along with a unique number designating the longitudinal position of the unit in the sampling reach (Appendices B & C).

Canals--No stratification of canal reach sampling by mesohabitat is required.

C. Sampling gears

Monitored target reaches vary greatly in terms of discharge, current velocity, geomorphology, species assemblage, etc., and sampling gear effectiveness also varies considerably across these conditions. Thus, sampling methodologies should be individually tailored to each situation.

Electrofishing has become perhaps the most widely-applied technique in fisheries surveys of running waters. Although it has potential for effecting muscle and spinal injuries and reducing growth and survival rates (Sharber and Carothers 1988, Snyder 1993, Dwyer and White 1995, Dalby et al. 1996, and others), Schill and Beland (1995) stress that population effects are usually negligible. This active sampling technique is effective with many species in a wide variety of shallow habitats (generally <2 m deep), but is best for collecting large-bodied species that inhabit the upper portions of the water column. Electrofishing can suffer from collector bias (selective sampling of species and sizes) in addition to the species/habitat biases just described. Electrofishing is ineffective in both very low and very high conductivity waters.

Seining is an active sampling technique most effective in capturing small-bodied species in shallow (<1.5 m deep), turbid, smooth-bottomed habitats. Seining does not usually exhibit significant collector bias, but is more limited in the types of habitats it can sample when compared to electrofishing. Mortality is not usually a problem except with very small individuals or in soft-bottomed habitats.

Gill nets, trammel nets, hoop nets, minnow traps, etc., are passive methods that depend on fish movements for capture, and catch rates may therefore be affected by variables such as water temperature, seasonal behaviors (e.g. migrations or spawning), etc. These methods are effective in sampling a wide variety of species and habitats, and are useful for capturing fishes that utilize deeper habitats difficult to sample by other techniques. Successful deployment of passive nets in flowing waters is limited by current velocity and amounts of drifting debris. Entanglement devices may cause fish mortality and physical damage depending on mesh size, species morphology, water temperature, and other factors.

Angling methods (including trot lines) are important sampling gears in deep-water habitats and for certain species ineffectively sampled by other methods. Choice of bait type strongly influences effectiveness of these gears, and thus baits should be standardized where possible. Angler skill is an important potential bias of the technique.

A wide variety of "hybrid" fish sampling methodologies may be applicable to special situations and habitats. For example, kick seining (physically disturbing substrate materials in a downstream direction toward a blocking net or dip net), drift netting (drifting unweighted trammel or gill nets through a habitat), or other innovative techniques (including use of stupefying substances) may effectively sample fishes where more traditional methods may not. Additional information on the practicalities of fish sampling gears can be found in Hendricks et al. (1980), Meador et al. (1993), and Murphy and Willis (1996).

Since a major goal of the monitoring program is to detect species presence/absence, a variety of sampling gears is used to avoid the species/habitat biases inherent with any single gear type

(Lundberg and McDade 1990, Meador et al. 1993). However, a second goal of the monitoring program is to detect trends in assemblage structure over time. Gear bias and incomparable effort units prevent pooling of species abundance data across gears unless they are precisely standardized and replicated each year.

Procedures

Streams--Electrofishing is the most widely applicable active sampling method over the widest variety of habitats. Unless habitats are absolutely not conducive to electrofish sampling, it is required that data obtained by electrofishing be used as the primary descriptor of assemblage structure at each fixed, quantitative 200 m station. Standardization of sampling by this technique therefore requires that electrofishing be employed first through each mesohabitat, as recommended by Meador et al. (1993). Mesohabitats should be sampled in an upstream progression with single-pass electrofishing, with pools sampled in an upstream direction, and swift-flowing mesohabitats sampled in a downstream direction into blocking nets. Electrofishing gears should be standardized to electrical configuration and power output when possible (Burkhardt and Gutreuter 1995). Research with rainbow trout *Oncorhynchus mykiss* suggests that pulse shape (Dalbey et al. 1996) and high pulse frequencies (or total amount of electricity delivered per unit time) (Sharber et al. 1994) are associated with high electrofishing-related injuries. However, Reynolds (1983) reported that higher pulse rates of 40-120 per second have greater effectiveness on small fish and minnows that are typical in smaller Gila River Basin streams. Dolan and Miranda (2004) recommended using continuous or pulsed DC with intermediate to high duty cycles. AZGFD guidelines for minimizing electrofishing injury recommend using pulsed DC, avoiding pulse rates above 60 Hz and pulse durations above 5 ms, and setting voltages between 150-1100 depending upon conductivity. Reclamation and its contractors shall make every attempt to adhere to the AZGFD guidelines. All electrofishing settings and outputs should be recorded on field the form (Figure 1).

Other methods should also be employed if the investigator considers sampling of a particular habitat inadequate by electrofishing. Because every habitat should be sampled at least partially by electrofishing, information from other gear type samples can only be used for species richness additions. Whenever possible, gear-type combinations should be consistently applied to a site over time, unless habitat changes dictate sampling modifications.

Canals--Because of sampling difficulties on the CAP and the array of techniques needed to sample it (Mueller 1989), it may not be possible to derive standardized assemblage structure indices in the CAP. Where possible, however, electrofishing sampling should be utilized as a primary sampling technique to facilitate comparisons with other target streams. The same is true for the SRP and FCG canals, but since they are typically sampled during periods of dewatering or flow cessation or reduction (see *Sampling periodicity* below), other sampling techniques may be more appropriate. Every effort should be made to precisely document sampling effort and standardize sampling procedures across sites and years for canal monitoring.

D. Sampling periodicity

Monitoring of fixed stations is conducted once annually. Sampling is typically conducted during autumn months to avoid most field problems of species identification (larval fishes should not be abundant) and variable stream discharge (stream flows should be near or at modal levels).

For standardization, autumn monitoring of fixed stream stations on the unregulated San Pedro River is restricted to the period September 1-November 30, when possible. Discharge to the Gila River downstream from Coolidge Dam is usually ceased beginning in late October for approximately one month, and monitoring should take advantage of the increase in sampling effectiveness during this time. Flows to the Salt River below Stewart Mountain Dam typically have been reduced during autumn-winter, and sampling there should similarly coincide with these events. The SRP and FCG canals should be monitored during dry-up periods that usually coincide with reductions in dam discharges. Changes in current Gila River and FCG flow regimes may occur after upgrades to FCG during winter 2011, and should be anticipated. Discharge reductions in the CAP canal are typically mid-summer for the portion upstream of Lake Pleasant and mid-autumn for the reach downstream of Lake Pleasant, and sampling must be scheduled during those times. For planning purposes, dewatering schedules should be obtained from the CAP, SRP and the San Carlos Irrigation Project well prior to sampling.

E. Sampling variables

Figure 1 shows the field form used to determine species richness, species distribution, assemblage structure, and supporting information. Appendix B provides definitions of the variables on these forms. To help ensure standardized collection of these data, Reclamation will provide a master of the form for use by investigators for recording of data. It is intended that a new fish collection form section be used in each habitat unit and for each change in gear type.

Certain header identifier information is common to all field forms. These variables include stream, reach, and station names (numerically coded for data entry), sampling date and time (a date and time in and date and time out is required for passive gears), habitat type name (pool, riffle, or run for streams; coded for data entry), and unique number for each habitat type within a stream station.

The fish collection form (Figure 1) also includes a variable describing whether the station is fixed or opportunistic, and what gear type is deployed. For electrofishing, pulse rate, voltage, and output amperage fields are provided. A water temperature reading is also required. The number of seconds electrofished, and the percentage of the mesohabitat area sampled should be recorded when quantifying sampling effort.

If seines or dip nets are deployed, mesh size and length and width (depth) of the gear is required. The number of seine hauls or dip net sweeps, and the percentage of the mesohabitat area sampled further quantify sampling effort for these gears (Figure 1). Data unique to entrapment and entanglement gears include mesh size and net length and width (depth), with effort quantified in hours soaked and automatically calculated from date and time in and out. Should sampling by angling or trot line be undertaken, bait type should be recorded, and effort in hours will be determined as above (Figure 1).

Data to be recorded from captured fishes at quantified stations include a four-letter code for species, an age category designation, the number of fish of a particular species and age, and the number of fish preserved for voucher (Figure 1, Appendix B). Reclamation recommends that all fishes, except small-bodied species such as mosquitofish, fathead minnow, red shiner, longfin dace, etc. be dichotomously classified to young-of-year (age-0) or older (age-1+) age classes. Appendix B provides definitions and additional notes on these variables.

Optional variables such as fish length, weight, sex, reproductive condition, number and kind of external parasites, external anomalies, and other notes should be recorded in the comments field.

Another important aspect of data sampling is recording of field notes. Field forms do not allow the type of narrative description of sampling site conditions, sampling problems, or other observational data that may be important to document sampling procedures or physical conditions at a particular site. To aid in compiling an overview of each stream sampling station, a sketch map should also be made to depict station morphology, including the distribution of mesohabitat types and their numbers. Reclamation will require recording and submission of legible field notes (or copies) from investigators. Reclamation may transmit copies of field notes to FWS, AZGFD, NMDGF, or other interested parties when submitting annual reports.

F. Permits

No federally-protected fishes are expected to be routinely encountered during monitoring of target reaches (Table 2), although this situation may change in the future. Voucher specimens are required from monitoring surveys (see *Voucher specimens* below) and listed or candidate species may be captured during monitoring. The incidental take statement in the Gila River basin BO serves as Reclamation's permit for take of federally-protected species during monitoring. However, all subcontractors will be required to obtain their own Federal and State collecting permits that authorize all potential species (Table 2).

G. Voucher specimens

Several (3+) specimens of each novel species encountered at each canal, river, stream, reach or sampling station should be preserved for museum vouchers, when possible, to be housed at the Arizona State University (ASU) Collection of Fishes. Quality photo-documentation of species not permitted for take should be made. Vouchers will provide scientific credibility to the monitoring project, ensure accuracy of species identifications in the field, and scientifically document species occurrence and distribution (Crossman 1980, Lee et al. 1982, Reynolds et al. 1994). Voucher specimens will be preserved in 10% formalin immediately following recording of pertinent field data. If specimen body depths are greater than approximately 3 cm (1¼ in), specimens should be cut along the right, lower body wall or injected with 10% formalin into the peritoneal cavity and major muscle masses to ensure adequate tissue fixation. Specimens should be retained in labeled, leak proof plastic jars or buckets until deposited at the ASU Collection of Fishes. Reclamation will provide rite-in-the-rain collection labels to investigators to ensure that taxonomic identification (if possible), date, time, and method of collection, locality, number of specimens, and collector name(s) are recorded for each sample. Reclamation will also periodically provide to ASU sufficient quantities of 95% ethanol (or monetary value thereof) to facilitate long-term storage of vouchers.

In the event that a new species or new distributional record is detected during sampling, contractors must notify Reclamation immediately so that we are able to inform FWS and AZGFD within five days of the collection, as stipulated in the BO. Reclamation will also notify appropriate individuals at ASU to determine if special collections may be needed for detailed analyses (e.g., frozen material for genetic study). Certainly such exceptional captures must also be documented under normal voucher specimen procedures.

H. Quality control and quality assurance

Quality control (QC), the techniques and activities that achieve, sustain, and improve the quality of a product or service, and quality assurance (QA), the components of a system that verify the QC steps are working properly (Geoghegan 1996), are invaluable components to a long-term monitoring project of this type. A detailed standard operating procedures (SOP) manual that describes standardized, repeatable field measurements is perhaps the most important aspect of the QC system for this project. Appendix C provides an integrated field SOP manual that identifies objectives of the monitoring program and specifies all field techniques and data collection procedures for canals, rivers and streams in an attempt to minimize ambiguity of field monitoring activities. It is anticipated that this manual will be updated and refined periodically based on cumulative field experiences. Revisions will document procedural changes that may occur over the course of the monitoring program.

I. Reporting

The contractor performing annual monitoring as described in this plan will produce an annual report for Reclamation that describes all collections from canals, streams and rivers. Data will be summarized in tabular and/or graphical form that for each location clearly relates fish species richness, relative abundance, and assemblage structure; see Objective 3, below, for additional information. The contractor also will furnish labeled digital site photographs and legible copies of field data forms and notes. Reclamation or a contractor will prepare a comprehensive, five-year report that provides yearly comparisons and examines any trends in species richness, relative abundance, or community structure.

Objective 3) Develop a statistical database in standardized format for storage and retrieval of long-term monitoring data.

To ensure timely evaluation of monitoring data, a rigid schedule for data entry, verification, screening, and tabulation will be required from all investigators using the procedure provide by Marsh and Kesner (2010a). Each investigator will be responsible for entry and verification of their data using the standardized variable names and formats listed in Appendix B. Investigators will submit all original or legible copies of field forms to Reclamation along with electronic data files. Reclamation will require submission of these data no greater than 90 days following completion of field sampling.

Data should be screened to flag possible outliers. Data will be tabulated by each investigator to show, for each sampling station, numbers of each species captured by each sampling gear, total effort expended by each gear type, and the proportion of age-0 to age-1+ individuals for each species captured. A narrative should accompany tabular data to describe what exactly was accomplished during sampling activities, and what deviations from established protocol were necessary.

Reclamation or a contractor will perform final screening of submitted data, and will analyze data according to procedures outlined under Objective 4. By May 1 of each year, Reclamation will provide interested agencies and individuals a written report with statistical results and conclusions regarding the annual monitoring period. A comprehensive report of accumulated annual data will be submitted every five years.

Objective 4) Identify statistical techniques to detect changes in monitored parameters.

The common goal of monitoring programs is to establish a norm and detect departures from it. In disturbed systems, such as target monitoring reaches identified here, determination of "normal" assemblage structure is problematic (Courtenay and Hensley 1980). A host of factors promote variability in assemblage structure (Moyle 1994), and distinguishing between natural and human-induced causes of variability is difficult (Grossman et al. 1990). In altered habitats, the presence of introduced species may contribute to this variability (Minckley and Meffe 1987, Moyle 1994). In addition, few baseline data are available from which to estimate the persistence of species assemblages.

A monitoring plan can be regarded as an attempt to test the null hypothesis that there is no change in a monitored parameter (Peterman 1990, Fairweather 1991). More specifically, biological monitoring is a continuous collection of data to establish whether explicitly stated quality control conditions are being met (Cairns and Smith 1994). Therefore, the essential aspect of statistical analysis of monitoring data is to be able to detect a change when a change has actually occurred, i.e., to be able to reject the null hypothesis. Failure to reject the null hypothesis when in fact it is false engenders a mistaken sense of security because it is concluded that no change has occurred when in fact there has, and nothing is done in response even though something should. Certain fisheries and marine mammal populations have been severely mismanaged, in some cases to the point of collapse, because data collection procedures were inadequate to allow rejection of the null hypothesis (de la Mare 1984, Peterman and Bradford 1987, White 1988, Peterman 1989).

The probability of accepting the null hypothesis when it is false, a Type II error, is estimated by β, and the statistical power of the test is determined by $1-\beta$. Thus, statistical power can be defined as the probability of detecting a difference when one exists. Statistical testing of monitoring data should maximize power in order to minimize the risk of a Type II error. Statistical power is proportionally related to the size of the effect to be detected (effect size), sample size, and the size of α, which estimates the probability of falsely concluding that a change has occurred (a Type I error, rejecting the null hypothesis when it is true). Power is inversely proportional to variability in the data. The generally accepted convention is that power should be equal to at least 0.8, or that α and β be equal (Cohen 1988, Peterman 1990, Fairweather 1991, Green and Young 1993, Hayek 1994). Reclamation will employ the convention where $(1-\beta)\geq 0.8$.

Establishing a criterion for the size of the effect to be detected is an essential procedure in the statistical design of a monitoring program. In other words, how much change is acceptable in the parameter being monitored before the resource is damaged? Power analysis can identify the tradeoffs that are often necessary between effect size and sampling effort.

Of the three monitored parameters of primary interest (species richness, species distribution, and assemblage structure), for our purposes the only requiring formal statistical evaluation is assemblage structure. Sampling design must be structured carefully to assure a reasonable probability of detecting the presence and distribution of a new species (Kovalak 1986, Green and Young 1993; see Objective 2), but statistics are not necessary to evaluate them. Detectability (the probability of species encounter; e.g., Bayley and Peterson 2001) or occupancy (the proportion of sites occupied by a species; e.g., MacKenzie et al. 2002) models can mathematically solve for biases of imperfect species detection methods, but ultimately they cannot identify which species were not detected during sampling. They also cannot predict the occurrence of novel species, a primary goal of this monitoring.

Analyses conducted on Gila River Basin monitoring data prior to 2000 were used to define the statistic for determining assemblage structure and sample sizes necessary to detect significant change through power analysis (Wilson 1995, Abarca and Allison 2000, Allison 2000). These reports recommended the use of absolute abundance of each species within a sampling station as the statistic to be monitored, but changes in abundance could only be detected for the most common species due to large variations in capture data from year to year (Allison 2000). Attempts to utilize the recommended standardized statistical test, ANCOVA, on data from 1995-1999 proved difficult, hampered by the frequency of catch data with zeros, autocorrelation of time series data, and a general lack of consistency in catch records. As a result of these investigations, it has been determined formal statistical treatment of monitoring data is not useful to inform the program about changes in target parameters, and that simple inspection of tabular or graphical data should be sufficient to adequately describe both current state and change over time (trend) in species richness, species distribution, and assemblage structure (e.g., Kesner and Marsh 2010b). The issue of statistical treatment of assemblage structure data will be revisited in future plan revisions as additional long-term data are acquired.

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Table 1. Sampling reaches, fixed station names (in parentheses) and lower boundary locations (UTMS, NAD83 Zone 12), and USGS quadrangle maps for canal, river, and stream fish monitoring, as of January 1, 2011.

Stream or canal reach	Fixed station (name) and location	USGS quadrangle map
San Pedro River		
US-Mexico boundary to Fairbank	**Upper** (Hereford) 584754E 3478766N	Hereford
	Middle (Lewis Springs) 581607E 3491385N	Lewis Springs
	Lower (Charleston) 578055E 3499565N	Fairbank
Fairbank to Redington	**Upper (**Hughes Ranch) 555099E	Soza Canyon
	Middle (Three Links) 566146E 3560579N (added 2005)	Wildhorse Mountain
Redington to Gila River	**Upper** (Aravaipa Creek) 526463E 3633954N	Lookout Mountain
	Middle (Dudleyville) 523343E 3644817N	Dudleyville
	Lower (Mouth) 522039E 3647432N	Winkleman
Gila River		
Coolidge Dam to Porphyry Gulch	**Upper** (Coolidge Dam) 543555E 3670085N	Coolidge Dam
	Lower (Hook & Line Ranch 541478E 3668433N	Coolidge Dam
Porphyry Gulch to Winkleman	**Upper** (Dripping Springs) 527159E 3660405N	Christmas
	Middle (Christmas) 526280E 3653633N (changed 2006)	Christmas
	Lower (O'Carroll Canyon) 524440E 3649531N (changed 2006)	Christmas
Winkleman to Mineral Creek	**Upper** (San Pedro River) 518933E 3649531N (changed 2002)	Winkleman
	Middle (Kearny) 507861E 3656465N (changed 2006)	Kearny
	Lower (Kelvin) 502767E 3662579N (changed 2006)	Kearny
Mineral Creek to Ashurst-Hayden Dam	**Upper (**A-Diamond Ranch) 498138E 3662779N	Grayback
	Middle (Cochran) 486273E 3663698N	North Butte
	Lower (Box Canyon) 478928E 3661520N (changed 2008)	North Butte
Salt River		
Stewart Mtn. Dam to Granite Reef Dam	**Upper** (Stewart Mountain Dam) 449608E 3712890N	Stewart Mountain
	Middle (Goldfield Administrative Site) 443056E 3713501N	Stewart Mountain
	Lower (Granite Reef Dam) 436512E 3541896N	Granite Reef Dam
CAP Canal		
Hayden-Rhodes Aqueduct	**Bouse Hills Pumping Plant**	Bouse Hill West
	Little Harquahala Pumping Plant	Hope SW
	Hassayampa Pumping Plant	Daggs Tank
Fannin-McFarland Aqueduct	**Salt-Gila Pumping Plant**	Granite Reef Dam
Tucson Aqueduct	**Brady Pumping Plant**	Picacho Reservoir
	Red Rock Pumping Plant	Red Rock
	San Xavier Pumping Plant	Brown Mountain
Florence-Casa Grande Canal		
Ashurst-Hayden Dam to Pima	**Above China Wash fish barrier**	North Butte
	Below China Wash fish barrier	Florence SE

Stream or canal reach	Fixed station (name) and location	USGS quadrangle map
lateral feeder canal	**Pima lateral turnout**	Valley farms
SRP Arizona (North) Canal		
Granite Reef Dam to electrical fish barrier	**Above fish barrier** (census)	Granite Reef Dam
Electrical fish barrier to Indian Bend Wash	**Below fish barrier** (opportunistic)	Granite Reef Dam Sawik Mountain Paradise Valley
SRP South Canal		
Granite Reef Dam to electrical fish barrier	**Above fish barrier** (census)	Granite Reef Dam
Electrical fish barrier to terminus	**Below fish barrier** (opportunistic)	Granite Reef Dam Mesa
Cienega Creek		
Pantano to Vail	**Upper** (Head Cut) 535470E 3541896N **Lower** (Three Bridges) 533435E 3542697N	Vail Vail

Table 2. Recent (since 1970) occurrence of fishes in target Gila River basin waters. SPR=San Pedro River north of Mexican border, GR=Gila River between Coolidge Dam and Ashurst-Hayden Dam, SR=Salt River between Stewart Mountain Dam and Granite Reef Dam, CAP=Central Arizona Project aqueduct, FCG=Florence-Casa Grande canal, SRP=Salt River Project canals, CCK=Cienega Creek between Pantano and Vail.

Common name	**Scientific name**	**SPR[2]**	**GR[3]**	**SR[4]**	**CAP[5]**	**FCG[6]**	**SRP[7]**	**CCK**
Gila chub[1]	*Gila intermedia*	-	-	-	-	-	-	+
Roundtail chub[1]	*Gila robusta*	-	-	+	-	-	+	-
Fathead minnow	*Pimephales promelas*	+	+	-	-	+	+	-
Goldfish	*Carassius auratus*	+	+	-	+	-	+	-
Longfin dace[1]	*Agosia chrysogaster*	+	+	+	-	+	+	+
Grass carp	*Ctenopharyngodon idella*	-	-	-	+	-	+	-
Grass carp X bighead carp	*Ctenopharyngodon idella X Aristichthys*	-	-	-	-	-	+	-
Carp	*Cyprinus carpio*	+	+	+	+	+	+	-
Red shiner	*Cyprinella lutrensis*	+	+	+	+	+	+	-
Spikedace[1]	*Meda fulgida*	-	+	-	-	-	-	-
Razorback sucker[1]	*Xyrauchen texanus*	-	-	-	+	-	-	-
Sonora sucker[1]	*Catostomus insignis*	+	+	+	+	+	+	-
Desert sucker[1]	*Pantosteus clarki*	+	+	+	+	+	+	-
Sucker hybrid	*Catostomus X Pantosteus*	+	+	+	-	-	-	-
Bigmouth buffalo	*Ictiobus cyprinellus*	-	-	-	-	-	+	-
Largemouth bass	*Micropterus salmoides*	+	+	+	+	+	+	-
Bluegill	*Lepomis macrochirus*	+	+	+	+	+	+	-
Green sunfish	*Lepomis cyanellus*	+	+	+	+	+	+	-
Smallmouth bass	*Micropterus dolomieu*	-	-	+	+	-	+	-
Redear sunfish	*Lepomis microlophus*	-	-	+	+	-	+	-
Sunfish hybrid	*Lepomis* hybrid	-	+	+	+	-	+	-
Black crappie	*Pomoxis nigromaculatus*	-	+	+	+	-	+	-
Black bullhead	*Ameiurus melas*	+	+	+	+	+	+	-
Flathead catfish	*Pylodictis olivaris*	+	+	+	+	+	+	-
Channel catfish	*Ictalurus punctatus*	+	+	+	+	+	+	-
Yellow bullhead	*Ameiurus natalis*	+	+	+	+	+	+	-

Common name	Scientific name	SPR[2]	GR[3]	SR[4]	CAP[5]	FCG[6]	SRP[7]	CCK
Gila topminnow	*Poeciliopsis occidentalis*	-	-	-	-	-	-	+
Mosquitofish	*Gambusia affinis*	+	+	+	+	+	+	-
Sailfin molly	*Poecilia latipinna*	-	-	+	-	-	-	-
Rainbow trout	*Oncorhynchus mykiss*	-	-	+	-	-	+	-
Walleye	*Stizostedion vitreum*	-	-	+	-	-	+	-
Yellow perch	*Perca flavescens*	-	-	-	-	-	+	-
Threadfin shad	*Dorosoma petenense*	-	+	+	+	+	+	-
Tilapia spp.	*Oreochromis, Tilapia*	-	-	+	-	-	+	-
Yellow bass	*Morone mississippiensis*	-	-	+	-	-	+	-
White bass	*Morone chrysops*	-	-	-	+	-	+	-
Striped bass	*Morone saxatilis*	-	-	-	+	-	+	-
Oscar	*Astronotus ocellatus*	-	-	-	-	-	+	-
Pacu	*Colossoma* sp.	-	-	-	+	-	-	-

[1]Native species
Sources: Reclamation data (Fall Fish Count surveys)[2,3]; J. Simms, BLM, personal communication[2]; J. Warnecke, AZGFD, personal communication[4]; FWS (1976)[4]; Mueller (1989), Bryan et al. (2000)[5]; T. Burke, USBR, personal communication, Bryan et al. (2000)[5]; Reclamation data[6,7]; Marsh and Minckley (1982)[7]; Wright and Sorensen (1995)[7]; Kesner and Marsh (2010b) [2-7]

Figure 1. Field data entry form.

STREAM NAME ____________ [ ]
REACH NAME ____________ [ ]
STATION NAME ____________ [.]

DATE & TIME IN [/ / :]
(E.G. 11/24/2010 14:55)
DATE & TIME OUT [/ / :]

HABTYPE ____________ [ ] HABNUM [ ] FIXED STATION (Y/N) [ ] GEAR TYPE ____________ [ ]

ELECTROSHOCK

PULSE/SEC [ ]
VOLTS [ ]
AMPS [.]
TEMPERATURE [.]
SECONDS [ ]

SEINES AND NETS

GEAR MESH (IN) [.]
GEAR LENGTH (FT) [ ]
GEAR WIDTH (FT) [ ]
NO. OF HAULS [ ]

ANGLER/TROT LINE

BAIT TYPE ____________ [ ]
NO. OF HOOKS [ ]

% HABITAT SAMPLED (SHOCK & NET) [ ]

NOTES ____

SPECIES	AGE (0/1)	NUMBER OF FISH	NUMBER OF VOUCHERS	COMMENTS

STREAM NAME ____________ [ ]
REACH NAME ____________ [ ]
STATION NAME ____________ [.]

DATE & TIME IN [/ / :]
(E.G. 11/24/2010 14:55)
DATE & TIME OUT [/ / :]

HABTYPE ____________ [ ] HABNUM [ ] FIXED STATION (Y/N) [ ] GEAR TYPE ____________ [ ]

ELECTROSHOCK

PULSE/SEC [ ]
VOLTS [ ]
AMPS [.]
TEMPERATURE [.]
SECONDS [ ]

SEINES AND NETS

GEAR MESH (IN) [.]
GEAR LENGTH (FT) [ ]
GEAR WIDTH (FT) [ ]
NO. OF HAULS [ ]

ANGLER/TROT LINE

BAIT TYPE ____________ [ ]
NO. OF HOOKS [ ]

% HABITAT SAMPLED (SHOCK & NET) [ ]

NOTES ____

SPECIES	AGE (0/1)	NUMBER OF FISH	NUMBER OF VOUCHERS	COMMENTS

RECORDED BY:__________ CHECKED BY:__________ ENTERED BY:__________