REVISION NO. 2

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

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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) on transportation and delivery of CAP water to the Gila River Basin (FWS 1994) determined that the project would jeopardize the continued existence of four threatened or endangered fishes: Gila topminnow *Poeciliopsis occidentalis*, 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 three 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 (AGFD) 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) 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; and 6) perennial reaches of the San Pedro River downstream from the U.S.-Mexico border. 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, 4) statistical techniques to be applied for data analyses, and 5) a rigid schedule for data analysis and review. Appendices provide standard operating procedure field manuals for use by investigators. In order to effectively manage parameters of interest, the plan calls for development of parameter threshold criteria to indicate when management actions are required, and management action recommendations to be undertaken to return monitored parameters within an acceptable range. A plan design without the latter two elements is more aptly termed "surveillance" (Cairns 1980).

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 (Objective 5), 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).

Monitoring of other parameters not specifically required by the BO are proposed here to enhance the ability to interpret monitoring data at only minor additional field effort and monetary expense. The availability of stream macrohabitats (i.e., pools, riffles, and runs) strongly influences fish abundance, species richness, and assemblage structure. The ability to attribute shifts in fish populations to changes in physical habitat (e.g., following a major flood; Harrell 1978) will be greatly enhanced by monitoring stream habitat availability and quantifying fishing effort within macrohabitats.

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, Reclamation proposes dichotomous categorization and enumeration of collected fishes to age-0 or older (age-1+) age classes. 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.

Objective 2) Identify statistical techniques to detect changes in monitored parameters, and develop effect size criteria or thresholds.

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 the "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), the only requiring formal statistical procedures for testing 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 3), but statistics are not necessary to evaluate them. The ability to detect a change or trend in assemblage structure, however, is a less straightforward exercise.

Reclamation contracted with Dr. Jeffrey R. Wilson of the Department of Decision and Information Systems at Arizona State University (ASU) to conduct a statistical power analysis of assemblage structure of three sample data sets from Gila River Basin monitoring studies. Data sets included Reclamation electroshock and seine collections from 1991-1993 Fall Fish Count surveys of fixed stations on the San Pedro River and the Gila River below Coolidge Dam, and seine collections from Dr. W.L. Minckley's (ASU) 1965-1990 Aravaipa Creek surveys. The former streams will continue to be monitored under requirements of the RPA; Aravaipa Creek is a relatively pristine system supporting an important native fish community that can serve as a regional reference site (Hughes et al. 1986, Moyle and Sato 1991). Assuming one or more of the monitored reaches may be targeted for rehabilitation and recovery of native fishes, Aravaipa Creek will be useful for estimating attainable conditions, and for quantifying natural variation in a relatively unaltered stream assemblage.

Primary objectives of the Wilson contract were to: 1) define the statistic to describe assemblage structure; 2) determine the sample sizes necessary to detect changes in assemblage structure at various effect sizes and levels of statistical power, with $\alpha=0.05$; and 3) recommend statistical procedures for future analyses of monitoring data, with emphasis on the ability to detect changes in assemblage structure over the shortest possible time period.

The Wilson final report is provided in Appendix 1. To summarize his results, absolute abundance of each species within a sampling station is the statistic to be monitored. Monitoring of absolute abundance can track both changes in species population size across time at a given site, as well as abundance relative to other species (assemblage structure). At levels of variability characterized in the Aravaipa Creek, San Pedro River, and Gila River data sets, fish collections containing moderate numbers of each species should be adequate to allow rejection of the null hypothesis of no change in relative abundance at power ≥ 0.8, with moderate effect sizes. For example, a 25% change in a species' relative abundance should be statistically detectable at power $\geq 80\%$ if at least 30 individuals of that species are collected in the smallest sample. If 60 individuals of a given species are collected, a 10% change in relative abundance should be detectable at power $\geq 80\%$. Detection of a 30% or smaller change in relatively rare species (<25 individuals collected per sample) would not be probable (Appendix I).

The recommended statistical design for treatment of monitoring data is a repeated measures nested analysis of variance (ANOVA) (Maceina et al. 1994; Appendix I). Repeated measures ANOVA will be applied at the station hierarchical level across years, i.e. we are primarily interested in detecting changes in species populations and assemblage structure over time at a given site. A repeated measures design partitions the variation of the dependent variable (abundance) due to species, time, and species X time interactions. Stratification by abundance of short-lived (≤ 3 years) and long-lived (>3 years) native and nonnative fishes will also be investigated for possible utility in monitoring of assemblage structure. Methods to incorporate discharge history into assemblage structure analyses will also be explored.

Because there have been questions raised by reviewers of the Wilson report that have not yet been fully addressed, Reclamation will further examine power and analysis issues of the monitoring plan in the near future. Reclamation believes that this delay should not preclude the continuation of field monitoring activities, however, although we recognize that certain methods may have to be modified if Wilson's conclusions prove inaccurate or flawed.

Objective 3) Determine sampling methods to collect monitoring data on species richness, species distribution, and assemblage structure in target reaches.

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).

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. Reach boundaries are presented in Table 1 and Figures 1-9. 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, Figures 10-12). 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, Figures 14-15). 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 feeder canal (Table 1, Figure 13).

B. Sampling stations

To estimate within-reach variance of monitored parameters, three systematic sampling stations will be permanently established within each geomorphic stream reach or designated canal reach, where possible (Table 1, Figures 1-15). 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 will be used for long-term temporal and spatial comparisons of fish communities in the monitoring program. Fixed stations will be 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, Figures 10-12). 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 could be established there except between the electrical fish barriers and Granite Reef Dam on the Arizona and South canals (Table 1, Figures 14-15). For this reason, sampling below the electrical fish barriers in the SRP canals will be opportunistic, varying according to sampling accessibility to structural features that may concentrate fishes. FCG canal sampling will also follow this pattern (no fixed sampling stations). These necessities will compromise statistical comparisons of changes in assemblage structure using the repeated measures ANOVA design.

To aid in evaluation of the representativeness of systematic sampling stations and enhance the capability of detecting new or rare species, random sampling of spatially and temporally-variable sites within target reaches, where possible, should be conducted. Such sampling should occur as field conditions (i.e., hydrology, land access) allow. Hydrology of all target reaches except those of the San Pedro River is artificially controlled, and thus effective sampling must be based on dam release schedules or canal dry-ups. For the San Pedro River, Reclamation has developed a randomized sampling schedule where one additional sampling event per reach will be undertaken annually (Table 2).

Species occurrence and abundance is influenced by availability of habitats. Thus, to minimize bias of assemblage structure estimates and ensure a representative sample, sampling effort should be proportional 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.

Because initially an invasion of a new species will likely consist of few individuals, sampling effort must be high enough to provide a reasonable probability of detecting it (Kovalak 1986, Green and Young 1993). Recent studies concerned with stream fish species-area relationships (Lyons 1992, Paller 1995a) showed that sampling a length of a minimum of 35 times the mean stream width was required to accurately rank abundance of common species in relatively species-rich streams (by electrofishing). Lyons (1992) reported that this criterion was also sufficient for detection and ranking of rare species in Wisconsin streams, but Paller (1995a) suggested that considerably longer reaches (35-158 stream widths) were necessary to collect all species in first- to third-order streams in South Carolina with seven-pass electrofishing. Required sample areas for estimation of species richness were approximately three times greater for single-pass electrofishing in the South Carolina study, but Paller (1995a, 1995b) determined that it was more cost-efficient to sample a large area with a single electrofishing pass than a small area with multiple passes. Compared to multiple pass removal sampling, Simonson and Lyons (1995) reported that a single upstream electrofishing pass was adequate to assess species richness, abundance, and assemblage structure of fishes in small Wisconsin streams.

To achieve objectives of the FWS Opinion, Reclamation proposes a combination of intensive quantitative sampling over a 200 m reach of stream and extensive qualitative sampling of uncommon habitats in contiguous reaches. Data from each 200 m quantitative sample will determine assemblage structure of common species, and extensive qualitative samples will 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 would satisfy the minimum length:width ratio=35 criterion of Lyons (1992). Based on Reclamation sampling experiences in 1995, intensive sampling of longer reaches does not ensure detection of rare species, and decreases the sampling efficiency of field crews.

Procedures

Streams--Systematic station sites were initially identified on USGS topographic maps, overflown by helicopter, and further defined in the field (Table 1, Figures 1-8). Some proposed sampling sites have not yet been visited on the ground due to right-of-entry restrictions. Systematic station locations span most of the reach length and they are approximately equidistant, depending on access points. Existing sampling stations from Fall Fish Count surveys were retained where possible. Downstream station boundaries will be marked either with rebar stakes, aluminum tags, or flagging, and further defined using the Global Positioning System (GPS). Upstream station boundaries will be 200 stream meters above the downstream boundary, measured along the thalweg with either a tape or hip chain. Upstream boundary locations may vary, depending on changes in channel sinuosity over time, and therefore they will 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 will consist primarily of the forebays immediately upstream from the pumping plants (Table 1, Figures 10-12). Opportunistic sampling will be necessary on the SRP and FCG canals (Table 1, Figures 13-15). Precise descriptions of sampling sites will be recorded by Reclamation or contracted investigators.

C. Macrohabitat sampling

Stream sampling stations will be stratified to the primary macrohabitat level (pool, riffle, or run as defined by Bisson et al. 1982 and Platts et al. 1983) to further partition the variance among species collections. The distribution and frequency of macrohabitat units along a river reach reflect channel geomorphology, and influence the structure of the aquatic community. By quantifying sampling effort according to macrohabitat, comparisons of species richness and assemblage structure among macrohabitat types across stations and years will be facilitated. Macrohabitat quantification will assess habitat availability and track habitat changes at sampling stations over time.

MacDonald et al. (1991) cautioned that use of habitat units may hinder monitoring efforts because little information is available on changes in habitat units over time, and few data have been published on the accuracy of habitat unit surveys under different flow conditions or by different survey teams. However, use of macrohabitat sampling in a monitoring program is the only way to acquire information on temporal and spatial changes of these units. By limiting the level of macrohabitat definition to relatively easily recognizable habitat units (pool, riffle, run), inter-team sampling variablility is reduced (Roper and Scarnecchia 1995). Inter-team variability can be quantified with a relatively simple field experiment.

There seems little utility in attempting to monitor changes in canal habitats or in quantifying fish populations associated with particular canal habitats. Only the FCG canal is not concrete-lined, and thus habitats are not expected to change in most instances except as required by structural modification. In addition, canals typically will be sampled during dry-up periods when conditions may be very different from what they were during periods of normal operation. To our knowledge, canal habitats have not been typed and defined in the literature, and canal habitats are probably sufficiently different from

stream pools, riffles, and runs to preclude application of stream habitat type designations to canals (but see Wright and Sorensen 1995). Therefore, canal stations will not be stratified by macrohabitat.

Procedures

Streams--When comparing blocked and unblocked electrofishing samples, Simonson and Lyons (1995) determined that use of block nets was probably not necessary for routine estimation of species richness, abundance, or assemblage structure over reach lengths approximately 35 times the mean stream width. Vadas and Orth (1993) reported similar results. Thus, Reclamation will not require blocking of station boundaries during sampling. Macrohabitat unit boundaries shall be identified with temporary flagged stakes . The type name of the habitat unit shall be recorded along with a unique number designating the longitudinal position of the unit in the sampling reach (Table 3). Length of the habitat type shall be measured with a meter tape or hip chain and recorded, and similarly measure and record three equidistant stream widths. Maximum depth of each habitat type and the dominant substrate category (Table 3) shall be recorded as additional estimators of habitat change over time.

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

D. Sampling gears

Target reaches to be monitored 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), 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., 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), Nielsen and Johnson (1983), and Meador et al. (1993).

Since a major goal of the monitoring program is to detect species presence/absence, use of a variety of sampling gears is recommended 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 macrohabitat, as recommended by Meador et al. (1993). Macrohabitats should be sampled in an upstream progression with single-pass electrofishing, with pools sampled in an upstream direction, and swift-flowing macrohabitats sampled in a downstream direction into blocking nets. Electrofishing gears should be standardized to electrical configuration and power output, if 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. If management agencies determine that fish injury is an issue in a particular sampling reach, Reclamation recommends that pulse rates be kept below 30 pulses per second, and a smooth pulse shape be used. All electrofishing settings and outputs should be recorded on field forms (Figure 16).

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 the sampling difficulties of 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 recommendations hold for the SRP and FCG canals, but since they should be sampled during periods of dewatering (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.

E. Sampling periodicity

To provide the maximum probability of detecting the presence of a new species promptly, monitoring should occur at frequent, perhaps seasonal, intervals. On the other hand, monitoring of population trends of relatively long-lived species may not require even annual surveys. Because the costs of monitoring fish are medium to high compared with other aquatic parameters (MacDonald et al. 1991), it is recommended that monitoring of fixed stations be conducted once annually. Sampling during autumn months is recommended 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 should be 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. For planning purposes, dewatering schedules should be obtained from the Salt River Valley Water Users Association and the San Carlos Irrigation Project well prior to sampling.

Spatially-random San Pedro River sampling stations (above) will be sampled on a temporally-random basis. Temporally-random sampling in concert with a standardized sampling schedule will increase the probability of early detection of new species. Table 2 identifies random sample locations and times for the San Pedro River for the next 10 years. Reclamation's contractor will adhere to that sampling schedule unless hydrologic conditions or climatic events prevent it. In those events, the next immediately available period for sampling will be utilized.

F. Sampling variables

Figures 16-17 show field forms to be used to determine species richness, species distribution, assemblage structure, and supporting information. Table 3 provides definitions of the variables on these forms. To help ensure standardized collection of these data, Reclamation will provide a master of the forms for use by investigators for recording of data. It is intended that a new fish collection form be used in each habitat unit and for each change in gear type.

Certain header identifier information is common to all field forms to ensure that data are relational in the database. These variables include stream, reach, and station names (numerically coded for data entry), sampling date and time, 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 16) also includes a variable describing whether the sample is quantitative or qualitative, and what gear type is deployed. For electrofishing, pulse rate, voltage, and amperage fields are provided. Conductivity and temperature readings are required to determine electrical power output (wattage). The number of seconds electrofished, and the percentage of the macrohabitat area sampled should also 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 macrohabitat area sampled further quantify sampling effort for these gears (Figure 16). Data unique to entrapment and entanglement gears include mesh size and net length and width (depth), with effort quantified in hours soaked or as net area soaked per time. Should sampling by angling or trot line be undertaken, bait type should be recorded, and effort will be determined by the product of the number of hooks and hours fished (Figure 16).

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 16). Reclamation recommends that all fishes, excepting perhaps small-bodied nonnatives such as mosquitofish, fathead minnow, and red shiner, be dichotomously classified to young-of-year (age-0) or older (age-1+) age classes. Table 3 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.

On the habitat sampling field form (Figure 17; required only for stream sampling), a single length measurement, three equidistant width measurements, and maximum depth should be measured in each stream macrohabitat to estimate habitat unit dimensions. Also, the dominant substrate present in each macrohabitat should be categorized. These data will provide estimates of habitat availability within a sampling station, and help track habitat changes within stations over time.

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 macrohabitat types and their numbers. Reclamation will require recording and submission of legible field notes (or copies) from investigators. We will transmit copies of field notes to FWS, AGFD, and NMGF when submitting annual reports.

G. Permits

No federally-protected fishes are expected to be routinely encountered during monitoring of target reaches (Table 4), 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. Reclamation will request that any subcontractor that may perform monitoring be designated as a subpermittee under Federal permit provisions. All subcontractors will be required to obtain their own State collecting permit.

H. Voucher specimens

Several (3+) specimens of each permitted species encountered at each 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 the 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, leakproof 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 AGFD within five days of the collection, as stipulated under RPA #2 in 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.

I. 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. Appendices 2 and 3 provide draft field SOP manuals that identify the objectives of the monitoring program and specify all field techniques and data collection procedures for streams and canals, respectively, in an attempt to minimize ambiguity of field monitoring activities. It is anticipated that these manuals 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.

Reclamation will also conduct a one-day training session for all monitoring field crews immediately prior to each year's autumn sampling periods. These sessions will identify field crew leaders, explain the purpose of the

monitoring procedures, and ensure that individual crews understand and apply the field methods in the SOP manual as consistently and objectively as possible. Electrofishing safety issues will also be addressed. When possible, QA follow-up with field crews during actual monitoring will be conducted by the Reclamation fishery biologist.

Another major QC/QA aspect of the monitoring program is detection and correction of keypunching errors. As discussed under Objective 4, Reclamation will provide a custom dBASE V program to all contractors that will allow double entry verification of all keypunched data. This procedure will prevent errors from occurring in the data processing stream before they enter the analysis step. It will be the responsibility of each contractor to double-enter their monitoring data, and obtain a legal copy of dBASE software.

Following receipt of these data, Reclamation will apply extensive error checking routines, which will include univariate and multivariate range checks. The error detection procedure will be refined as additional errors undetected during the first routine are discovered during descriptive and statistical analyses.

Finally, a subset of database records (sample size to be determined from tables of Wetherill and Brown 1991) will be randomly selected and compared to original field data sheets. As recommended by Geoghagen (1996), Reclamation will initially set the acceptable quality level at 1% (no more than one error in any variable in 100 lines of data), with the intent of decreasing it in the future, if possible. The data processing stream that goes into producing tables and figures in annual reports will also be verified by a reviewer to assure data quality. If the database, figures, or tables fails these audits, the quality control process will be reevaluated and modified appropriately.

J. General

It is stressed that implementation of the above procedures in the first few field seasons will be considered a pilot project. Certain methodologies may require modifications for ease of application, or certain objectives may need to be scaled back if methods prove infeasible or data variability is greater than expected. Monitoring investigators will meet with Reclamation, FWS, and AGFD biologists following the initial field implementations to discuss sampling problems and recommend procedural modifications to maximize the efficiency of data collection and analysis.

Objective 4) 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. Reclamation will provide a copy of a dBASE V data entry and verification program to all investigators to facilitate data entry and format standardization. Each investigator will be responsible for entry and verification of their data using the standardized variable names and formats listed in Table 3. Investigators will submit all original, or legible copies of, field forms to Reclamation along with the electronic data files. Reclamation will require submission of these data no greater than 90 days following completion of field sampling.

Initial data entry by investigators must be verified by double entry. In the future, development of optically scannable field forms will be pursued to simplify and speed data processing (Conquest et al. 1994). 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 in a particular habitat type by each sampling gear, total area of each habitat type available at the sampling station, total effort expended by each gear type for each habitat 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 will perform final screening of submitted data, and will analyze data according to procedures outlined under Objective 2. By May 1 of each year, Reclamation will provide FWS, AGFD, NMGF, and interested 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 5) Develop a management action plan to be implemented if new nonnative species are detected or assemblage structure or distribution criteria are exceeded in target reaches.

Following acceptance of this monitoring plan by FWS, AGFD, and NMGF, Reclamation recommends that management agency biologists and other knowledgeable individuals immediately meet to jointly assess nonnative fish invasion, distribution, and assemblage structure change contingencies, and attach associated management action recommendations to each contingency. Recommendations will be submitted to management agencies for their consideration and potential implementation should the need arise. Inherent within these assessments would be the definition of what level of change constitutes a difference of practical significance (McBride et al. 1993). Actions could include renovation of the affected stream or reach with or without construction of fish barriers, selective removal of species during intensive sampling, design of regulations to enhance harvest of species, initiation of formal reconsultation with FWS, delivery of controlled flooding if the affected reach is downstream from a storage reservoir, possible habitat modifications, or other innovative techniques designed to reduce or eliminate negative impacts on native fishes. By expending this effort prior to detection of a possible management action event, valuable time will be saved by reducing discussions of action scenarios. In addition, compliance with National Environmental Policy Act and other appropriate laws and regulations must be completed and in place for urgent action. A list of potential vendors from which to readily procure ichthyocides and other materials should be prepared. These steps are considered essential to development of a management action plan.

In the event of detection of a new nonnative species in a monitored reach (see Table 4 for a list of species expected from each sampling reach), the first level of management action to be considered should be immediate intensive investigation of the species' distribution and relative abundance. Reach-wide surveys should expand both upstream and downstream from the point of detection to include all areas potentially accessed by the new species. Mobilization of personnel in addition to the original monitoring team will likely be required for this increased sampling effort. Literature and expert review of the species' potential impact to native species should be initiated. Consideration of a research study to investigate effects of the incursion on native species is also a possibility during this phase.

During this open-ended period of intensive monitoring, managers and species experts should meet to determine possible additional management actions identified in the management action plan. The group should formalize their recommendations for consideration by management agencies for implementation. A similar process should be implemented in the event that assemblage structure

criteria are exceeded. Management actions will be funded by the FWS Nonnative Management Fund established under the Gila River Basin BO (RPA #4).

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