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The Application of Fisheries Management Techniques to Assessing Impacts

Final Report

Prepared by D. H. McKenzie, M. A. Simmons, J. R. Skalski

Pacific Northwest Laboratory
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U.S. Nuclear Regulatory
Commission

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Manuscript Completed: August 1982
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Office of Nuclear Reactor Regulation
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ABSTRACT

Monitoring methods used in fisheries management assessments were examined and their potential applicability in confirmatory impact monitoring were evaluated using case studies from selected nuclear power plants. A report on Task I of the project examined the application of Catch-Per-Unit-Effort (CPUE) techniques in monitoring programs at riverine, large lake and ocean sites. Included in this final report is an examination of CPUE data for the Oconee Nuclear Plant on Lake Keowee, a reservoir site. This report also presents a summary of results obtained over the life of the project and guidelines for designing and implementing data collection programs and for data analysis and interpretation. Analysis of monitoring data from Lake Keowee confirmed findings from previous analyses of surveys at nuclear power plants on large lakes, rivers and coastal sites. CPUE techniques as applied to these monitoring programs do not provide data necessary to separate changes induced by plant operation from naturally occurring changes.

ABSTRACT

Monitoring methods used in fisheries management assessments were examined and their potential applicability in continuous impact monitoring were evaluated using case studies from selected nuclear power plants. A report on Task 1 of the project examined the application of Catch-Per-Unit-Effort (CPUE) techniques in monitoring programs at riverine, large lake and ocean sites. Included in this final report is an examination of CPUE data for the Oconee Nuclear Plant on Lake Lanier, a reservoir site. This report also presents a summary of results obtained over the life of the project and guidelines for designing and implementing data collection programs and for data analysis and interpretation. Analysis of monitoring data from Lake Lanier confirmed findings from previous analyses of surveys of nuclear power plants on large lakes, rivers and coastal sites. CPUE techniques as applied to these monitoring programs do not provide data necessary to separate changes induced by plant operation from naturally occurring changes.

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1.0 INTRODUCTION

As the state-of-the-art and technology of siting, construction, and operation of major thermoelectric power plants progresses, it is reasonable to expect that the severity and probability of significant aquatic impacts will decline. However, there will always be a degree of uncertainty about the ecosystem response to the added stress resulting from the operation of power plants. Thus, it is anticipated that monitoring programs will be conducted at some level of effort during several years of plant operation. The appropriate level or methodology of monitoring in these circumstances has not been explored sufficiently to allow definitive decisions concerning these factors.

The current state-of-the-art of power plant siting is such that potential for reduction of a fishery during power plant operation can reasonably be separated into two general categories: (1) power plants whose effects are expected to be small, but of some significance and (2) those that will have a very low potential for producing significant effects. The need and scope of monitoring programs should reflect these differences in impact potential.

When potential for suppression of a fishery is judged to be significant, the objective of a monitoring program should be to quantify that potential or estimate the magnitude of impacts. Numerous problems, approaches and research areas have been identified (Van Winkle 1977 and Reynolds 1980) for monitoring power plants in this category.

For those sites where potential for depletion is judged as probably not significant, the objective is to confirm that predictions of insignificant impacts were indeed correct. The design of monitoring programs under this minimal impact circumstance is the subject of this report.

The scope of this report is restricted to programs that monitor only a few selected finfish or shellfish population(s). These species were selected because of their value to the aquatic resource. These species were also situated at or near the top of the trophic structure and would likely indicate any significant impacts in lower trophic levels. Thus, some supportive rationale for a restricted monitoring approach is apparent.

One result of adopting such a restricted approach is subsequent reduction in ability to identify cause and effect relationships. If assignment of responsibility for impacts and design of mitigative or remedial actions is a requirement of a monitoring program, then efforts beyond the approach contained in this report are required. In general, limited predictive ability and complexity of potential cause and effect relationships suggests that a program of considerably greater complexity would be necessary (Thomas et al. 1981). The objective of the monitoring programs addressed within this report is one of detection of major population change in a few selected finfish or shellfish populations.

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2.0 KEOWEE RESERVOIR GILL NET DATA

Analysis of the fish monitoring data for the Oconee Nuclear Power Plant (NPP) represents the final stage in an assessment of the application of fishery management techniques to monitoring programs. A previous report (McKenzie et al. 1980) evaluated catch-per-unit-effort (CPUE) techniques for monitoring programs at nuclear power plants located on riverine, lake and ocean sites. This report examines the monitoring program for a power plant (Oconee NPP) constructed in conjunction with a reservoir (Lake Keowee). Monitoring programs in such a situation face unique problems since resident fish populations are in transition as the habitat changes from lentic to lotic. These changes continue for several years after the reservoir is filled until habitats are established and population dynamics stabilize (Baxter 1977; Neel 1967).

Objectives in evaluating the Oconee NPP monitoring program were to:

- evaluate the ability of CPUE techniques to monitor population dynamics in a reservoir habitat
- examine the sources and magnitude of the variability in CPUE data
- investigate the survey design, including an assessment of precision
- compare traditional CPUE statistics with a measure based on binomial probability.

CPUE, as an index of population size, is generally assumed to depict seasonal and annual changes in population size. Population changes related to impact from a NPP should then be superimposed on such seasonal factors as migration, spawning activity and recruitment. Qualitative (plots) and quantitative (regression analysis) methods provide a means for visualizing and describing these cycles.

The second objective relates to identifying the sources and magnitude of the variability in CPUE data. To demonstrate changes in population size due to impact, changes related to impact would have to be greater than those occurring naturally or associated with sample variability. Natural factors, inducing variation in CPUE data, will be represented as yearly and seasonal changes in abundance. Non-uniform spatial distribution within the reservoir can magnify these differences and may also impart additional sources of variability. And finally, the sampling method itself will contain an amount of variation due to sampling error and gear selectivity. Gear selectivity can change with time of year, environmental conditions and the fish population characteristics.

The third objective was to examine the survey design to determine if it would allow evaluation of the effect of the NPP on a fish population. Aspects considered were whether the design included control-treatment

comparisons and if CPUE based on single or multi-species data was more precise. Information on precision could be used to establish guidelines for sampling protocols.

During evaluation of catch data for this and previous monitoring programs, the quantal nature of the data became apparent. For a majority of the sampling methods used in the surveys, fish were either caught in abundance or were absent. We hypothesized that a statistic which measured presence/absence would provide information on impacts and would be less variable than CPUE. Data from the monitoring program at Oconee NPP provided a means of testing this hypothesis. The gill net sampling involved setting ten nets at each station, with catch data reported for each net. A presence/absence statistic was computed by assigning a zero if no fish were caught in a net or a one if fish were present. Summing this statistic for the ten nets yields a statistic we termed "net success." Analyses using both CPUE and net success were compared to evaluate the usefulness of net success as a monitoring statistic.

2.1 SITE DESCRIPTION

Oconee Nuclear Power Plant is operated by Duke Power Company. Located in Oconee County, South Carolina, the Oconee site consists of two reservoirs, Lake Keowee and Lake Jocassee (Figure 1), which were constructed in conjunction with the power plant. Construction at the site began in 1968, with complete fill of Lake Keowee occurring in 1971. Power plant operation began in 1973 after Lake Jocassee filled and reached full power in December, 1974. Hydroelectric facilities are located at both Keowee and Jocassee dams. At peak loads, the facilities withdraw 19,800 cubic feet per second (cfs) from Lake Keowee and 29,000 cfs from Lake Jocassee. At Jocassee Dam, the turbines are reversible and water can be pumped up Lake Jocassee during periods of lower power demand (minimum rate: 26,000 cfs).

The aquatic monitoring program began at Lake Keowee in mid-1972. Abundance and life history data were obtained by electroshocking and gill netting for adult fish, while data on larval fish were obtained from seine and frame net surveys.

We selected the gill net survey for evaluation because replicate sampling was incorporated into the design and four years of data were available. Initiated in September of 1972 and terminating in November of 1976, sampling initially included three stations and was expanded to four after two months. Station 1 was located 0.2 to 1 km from Oconee NPP; station 2 was 3 to 7 km from the plant in the north basin. Both stations 3 and 4 were 10 to 15 km from the plant, with station 3 in the south basin and station 4 1 to 2 km from Jocassee Pumped Storage Plant (Figure 1). Ten multifilament nylon gill nets (45.5 x 1.8 m containing three panels each of five mesh sizes - 34, 38, 51, 63 and 76 mm bar mesh) were set between 1200 and 1500 hours at each station and removed between 0900 and 1100 hours the following day. The number of monthly samplings per year varied from eight in 1974 to eleven in 1976.

FIGURE 1. Location of Oconee Nuclear Station (U.S. Atomic Energy Commission, 1972. Final Environmental Statement related to operation of Oconee Nuclear Station Units 1, 2 and 3.)

To evaluate information provided by the gill net survey we analyzed both the total catch and the catch of selected fish species. Species selection was based primarily on catch abundance. The gill net survey collected twenty-seven of the nearly fifty fish species identified from Lake Keowee (Appendix A). Six of these, representing more than seventy percent of the catch for any one year, were selected for analysis. The selected species were: carp (Cyprinus carpio Linnaeus), silver redhorse (Moxostoma anisurum [Rafinesque]), flat bullhead (Ictalurus platycephalus [Girard]), bluegill (Lepomis macrochirus Rafinesque), largemouth bass (Micropterus salmoides [Lacepede]) and black crappie (Pomoxis nigromaculatus [Lesueur]).

The six species occupy diverse habitats and trophic levels. Bottom feeding omnivores are represented by carp and flat bullhead; bluegill is an omnivore inhabiting more open water. Bluegill occupy small, shallow-water territories in summer and move, in schools, to deeper water during the winter. Silver redhorse and black crappie are insectivores. Black crappie school and feed in open water during early morning hours before and after sunrise. Silver redhorse, belonging to the sucker family, is a bottom dwelling fish. Carnivores are represented by largemouth bass, which inhabits the upper levels of warm water lakes in summer, moving to the bottom in winter. All these species spawn during spring or early summer.

2.2 ANALYSIS

Evaluation of the gill net data from Lake Keowee involved the following statistical methods:

- regression and correlation analysis
- one-way analysis of variance
- Chi-square contingency table.

Plots of CPUE data served as graphical aids in interpreting analytical results throughout the analysis.

Copies of original data sheets were supplied by Dr. Clugston of the Southeast Reservoir Investigations, U.S. Fish and Wildlife Service. Catch data were provided by date, station, net and species. CPUE and net success were computed for six selected species and total catch (i.e., all species). CPUE was calculated as the average catch-per-net for each date and station. Net success was computed as the number of nets which caught one or more of the selected species. For example, a net success of six meant that six nets (out of ten) contained fish.

An assumption of analysis of variance and regression analysis is that the data are normally distributed with constant variance. Plots of CPUE and its variance suggested a Poisson distribution with variance proportional to the mean. Count data such as net success also tend to be Poisson distributed. To normalize the data and reduce the association between the

variance and mean, the data were square-root transformed before analysis. It is recognized that transformation of the data can alter the outcome of test results, especially interaction effects that are influenced by the scale of measurement. There were, however, no significant differences between ANOVA results using transformed and nontransformed data.

2.2.1 CPUE and Population Dynamics

One objective of this effort was to determine if yearly and seasonal trends in catch data could be distinguished from inherent variability of the sampling method. To examine yearly and seasonal trends, CPUE and net success by species and station were plotted against time. Stepwise multiple regression analysis was used to determine the fit of a linear function to the observed data. The stepwise regression procedure involves adding variables to the regression equation based on the reduction in sum of squares of the dependent variable. The variable giving greatest reduction is entered first, followed by the variable contributing the next greatest reduction. This process continues until any additional reduction is too small to improve the fit of the equation to the data significantly. For CPUE regressions, variables were date (0-365), date squared, date cubed, date to the fourth power, and variable (zero-one), representing the sampling years (1973-1976).

2.2.2 Variability in CPUE

Another objective was to examine inherent variability of the sampling technique. Variability was examined by three test statistics. A pooled estimate of the variance among replicates (s_p^2) provided an assessment of total variation for each species/station pair. This measure of variation was computed as:

$$s_p^2 = \frac{\sum_{i=1}^d s_i^2}{d}$$

where
$$s^2 = \left[\sum_{i=1}^n k_i^2 - \left(\sum_{i=1}^n k_i \right)^2 / n \right] / (n - 1)$$

and where d = number of sampling periods estimate is pooled over

n = number of replicate nets in sample period

k_i = number of fish captured in i th net ($i=1, \dots, n$).

A coefficient of variation (C.V.) was used to examine the temporal pattern of variation. C.V. was calculated for each sampling date and plotted versus time. Comparisons were also made between the C.V. for CPUE and that for net success (see section 2.2.5). A third statistic, an analysis of variance for factorial treatment designs, identified significant sources of variation. Sources for this analysis consisted of sampling date, year and station. No effect from operation of Oconee NPP was included in the model as operation effects cannot be separated from year effects. Observations were conceptualized as being in a completely randomized design for analysis of variance. No interaction term of order three or greater was included in the analysis of variance model. The assumption here was that higher order interaction terms were not significant and could be included in the error term. Factors affecting CPUE and net success were assumed to be fixed effects, restricting inferences to the factors and their levels observed in the monitoring program. Factors and their levels of treatment for gill net survey data at Lake Keowee can be summarized as:

- A. Years of data analyzed; $a = 1, 2, 3, 4$
- B. Sampling dates per year; $b = 1, 2, \dots, 6$
- C. Sampling station; $c = 1, 2, 3, 4$

Different factors at their various levels defined 96 ($4 \times 6 \times 4$) distinct treatment combinations in the factorial treatment design. With large factorial treatment designs characteristic of monitoring programs, lack of balance and/or orthogonality can produce uninterpretable results. For this reason a subset of the available data which was both balanced and orthogonal was used in the analysis of variance. An additive ANOVA (analysis of variance) model was assumed and can be written as:

$$\sqrt{Y_{abc}} = \mu + A_a + B_b + C_c + AB_{ab} + AC_{ac} + BC_{bc} + \epsilon_{abc} \quad (1)$$

where Y_{abc} = CPUE or net success for spatial-temporal sample described by factors A, B, C at appropriate levels.

μ = overall mean effect.

A_a = main effect of factor A (years), $a=1, 2, 3, 4$.

B_b = main effect of factor B (sampling date),
 $b=1, 2, \dots, 6$.

C_c = main effect of factor C (station),
 $c=1, 2, 3, 4$.

AB_{ab} = two factor interaction effect (years x dates).

ϵ_{abc} = additive error term.

The spatial-temporal homogeneity of the fish community at Keowee Reservoir was investigated by analyzing model (1).

2.2.3 Survey Design

A third objective was to examine sampling design. Some relevant questions were: Does the study design allow for control-treatment comparisons? Does species composition change with station location? These questions require information on the effect of station location on spatial and temporal distribution of the six species. Analysis involved correlation and chi-square statistics. The chi-square test evaluated spatial distribution. For this analysis, total yearly net success for each species and station was determined. The null hypothesis for the resulting 6x4 contingency table was that species composition was independent of station within any sampling year.

Correlation analysis evaluated the temporal distribution of the six species within the reservoir, i.e., similarity between stations in temporal pattern of CPUE. Significant correlations indicate that processes controlling population dynamics occurred at the same time at all sampling stations within the reservoir.

2.2.4 Precision

Another aspect of survey design examined was whether catch statistics computed for a single species or for total catch were more precise. Error terms from regression and ANOVA analyses, as well as the pooled estimate of variance (s^2) were compared. Correlation analysis was used to determine if any species exhibited similar patterns in abundance over the sampling period.

2.2.5 Comparison of Analysis Methods

In choosing to analyze the gill net catch data using both traditional CPUE statistic and a measure based on binomial probability, our interest centered on examining variability associated with these two methods. Where possible, comparable analyses were performed using CPUE and net success. Means and variances for net success were computed as:

$$\hat{\mu}_i = n\hat{p}_i$$

$$\hat{\sigma}_i^2 = n\hat{p}_i(1 - \hat{p}_i)$$

where n = sample size (number of nets)

$\hat{p}_i$ = estimated probability of capturing an individual of species i in a net (number of nets capturing fish/total number of nets set).

2.3 RESULTS

2.3.1 CPUE and Population Dynamics

Plots of CPUE data as a function of sampling date, generally reveal two to three abundance peaks per year (Appendix B). For nearly all species and station combinations, one peak occurs in spring and appears to coincide with spawning activity. In addition to spawning activity, several species migrate to shallower waters from deeper waters they inhabit during winter (Scott and Crossman 1973, Meyer 1962). Other peaks occur in late summer and fall, and may represent recruitment from previous year's spawning.

For several combinations of species, station and year, little or no pattern in CPUE existed. The most prominent examples included silver redhorse at station 3 and bluegill at all stations in 1975 and 1976. Catches for these species were extremely low at these locations and times and no trends or peaks were apparent.

Plots of CPUE also revealed differences in patterns of abundance between species and between stations for the same species. These differences occurred either in timing or in relative sizes of abundance peaks. For example, the spring peak in CPUE for silver redhorse varied by a month or more, depending on station and year. At station 1, the spring peak occurred as early as February in 1974 and as late as May in 1975; at station 2, the spring peak in 1975 was in April. Physical characteristics of each station and their influence on water temperature, i.e., spring warming and fall cooling, are probable factors contributing to this range. Station differences also appear to influence species composition. At station 3, where five of the six species examined were abundant, patterns of abundance were different, with CPUE for carp, bullhead, and bluegill being higher in spring than in fall, while the opposite occurred for largemouth bass and black crappie CPUE.

Trends in population size over the four years of study were also apparent in the plots. For example, number of carp in the samples declined, while number of flat bullhead and black crappie increased. Bluegill catch represented the most dramatic change, going from 10% of the total catch in 1973, to a negligible fraction in 1976.

Our next step in the analysis involved quantifying the relationship at each station between CPUE (square root transformed) and time using stepwise regression analysis. Using multiple regression, a polynomial expression in powers of Julian date (0, ..., 365) was constructed. Indicator variables (0, 1) were adjusted for yearly changes in fish abundance. The resulting equations were generally significant for all species except for black crappie, and explained about 30 to 40% of the variation in CPUE (Table 1).

TABLE 1. Regression Coefficients for CPUE (Square Root Transformed)

Station	Date	Date ²	Date ³	Date ⁴	Year 3	Year 4	Year 5	Year 6
<u>Carp</u>								
1	.0164	-.6857E-4		.2094E-9	-.0337		-.2450	-.3952
2	.0058		-.1142E-6	.1894E-9	-.0482		-.0390	-.1364
3	.0187	-.7193E-4		.1918E-9	.2228		-.0394	-.3075
4	.0055		-.0579E-6	.0484E-9	.2671	.2253		
<u>Silver Redhorse</u>								
1	.0106	-.7253E-4	.1270E-6		.0378		-.0783	.1066
2	.0086	-.5587E-4	.0937E-6		.2349		-.0334	.0154
3	.0014	-.0835E-4		.0369E-9	.0723	.1368		.0536*
4	.0120	-.4695E-4		.1229E-9	.4395	.6613		.0498
<u>Flat Bullhead</u>								
1	.0054	-.2519E-4	.0330E-6			.0226	.2089	.4838
2	.0026		-.1032E-6	.2577E-9	.0253		.2602	.3766
3	.0080	-.3343E-4		.0948E-9	-.5134	-.2164	.1177	
4	-.0032		.1198E-6	-.2526E-9	-.1147			-.1845
<u>Bluegill</u>								
1	.0027		-.0882E-6	.1985E-9	.3051	.0875		-.0271
2					.2563	.1128	.0500	
3	.0009		-.0153E-6	.0154E-9	.3332	.1857		-.1089
4	-.0002	-.0105E-4		.0098E-9	.1189	.0768	.0137	
<u>Largemouth Bass</u>								
1	-.0032	.1889E-4		-.0871E-9			.0902	.0503
2	-.0012	.0931E-4		-.0505E-9	-.0845	.0376	.0904	*
3	-.0039	.2336E-4		-.1080E-9	-.0964	-.0427		.0232
4	-.0029	.1656E-4		-.0524E-9	.0222	-.0515		.0538
<u>Black Crappie</u>								
1	-.0002		-.0141E-6	.0460E-9		-.0993	.1244	-.0189*
2	.0015	-.0329E-4		-.0101E-9		-.0636	.1864	.0144*
3	.0022	-.1020E-4		.0501E-9		-.0743	.1935	*
4	-.0030		.0806E-6	-.1624E-9	-.0867		.2887	.0597

*Regression equation not significant ($\alpha = 0.05$).

At three of four sampling stations for black crappie, regression equations were not significant ($\alpha > 0.05$).

In analyzing the regression equations, size and sign of coefficients for date variables were indicative of amplitude and timing of abundance peaks (Table 2), while coefficients for year variables were indicative of magnitude of catch in a particular year. For carp, silver redhorse and largemouth bass, there was a significant polynomial relationship between CPUE and sampling date. The polynomial generally incorporated the date variable and at least one additional power term. This relationship was also noted for flat bullhead CPUE at station 3. For the other species, bluegill, black crappie and flat bullhead at stations 1 and 2, CPUE appears to be related only to sampling year. For those species, no regular pattern in CPUE within years is apparent.

2.3.2 Variability in CPUE

Several statistics were employed to characterize CPUE variability. The first statistic, a pooled variance estimate (s^2) provides a measure of the variation between replicate net settings for the catch in each species/station pair. For square root transformed catch data, estimates ranged from 0.192 to 0.397 (Table 3). Species at station 4 generally had the highest estimates, while estimates for data collected at station 3 were generally lowest.

A second measure of the relative variability, the coefficient of variation (C.V.), was used to estimate the variability in CPUE for each sampling date. C.V. for each species-station pair (Table 4) was inversely proportional to CPUE. Plots of C.V. versus time produced a pattern just reversed from that noted in plots of CPUE versus time; and consequently those species with high CPUE had low C.V.'s and vice versa. Table 5 presents C.V.'s for CPUE and net success calculated from ANOVA error mean square.

A factorial analysis of variance (ANOVA) identified sources of variation in CPUE by evaluating effects of sampling date, year and station, and their interactions. Table 6 summarizes the significant main effects ($\alpha = 0.05$) and interactions. Results of factorial ANOVA revealed that differences in CPUE for most species are significantly related both to sampling time (date and year) and station. Exceptions occur for bluegill and black crappie, where effect of sampling date was not significant. For largemouth bass, date was the only significant factor affecting CPUE. The majority of significant ($\alpha = 0.05$) interactions involved station position by year. Date by year interactions were significant for carp and black crappie.

2.3.3 Survey Design

Separate analyses examined spatial and temporal distribution of the six species within the reservoir. Examination of temporal distribution involved correlation analysis. In this analysis, temporal pattern in CPUE was compared for each station combination. A significant correlation coefficient

TABLE 2. Stepwise Multiple Regression Statistics for Fish Monitoring Survey at Lake Keowee. Dependent Variable: CPUE (Square Root Transformed)

Station 1			Station 2			Station 3			Station 4		
Order of Variables	R ²	S ² _{y.x}	Order of Variables	R ²	S ² _{y.x}	Order of Variables	R ²	S ² _{y.x}	Order of Variables	R ²	S ² _{y.x}
<u>Carp</u>											
Date ⁴	.092	.424	Date ⁴	.082	.308	1973	.131	.511	1973	.093	.323
Date ²	.207	.402	Date	.266	.279	1976 ⁴	.152	.512	Date ³	.174	.313
Date ²	.376	.362				Date ⁴	.177	.512	Date ³	.481	.251
1976	.470	.339				Date ²	.370	.454	1974	.550	.238
						Date ²	.500	.411			
<u>Silver Redhorse</u>											
Date ²	.160	.230	1973 ³	.226	.235	Not Significant			1974	.214	.379
1976	.223	.225	Date ³	.301	.226				1973 ⁴	.442	.324
Date ³	.258	.223	Date ²	.312	.227				Date ⁴	.484	.316
Date ³	.432	.197	Date ²	.424	.211				Date ²	.606	.280
1975	.457	.197							Date ²	.697	.249
<u>Flat Bullhead</u>											
1976	.381	.246	1976	.167	.282	1973	.326	.272	Date ³	.239	.290
			1975	.291	.264	1974 ⁴	.442	.251			
						Date ⁴	.487	.244			
						Date ²	.535	.235			
						Date ²	.611	.219			
<u>Bluegill</u>											
1973	.350	.188	1973	.321	.132	1973	.328	.218	1973	.255	.076
						1974	.466	.197	Date	.377	.070
									1974	.476	.065
<u>Largemouth Bass</u>											
Date ²	.130	.124	Not Significant			Date ²	.174	.155	Date ²	.370	.156
1975 ⁴	.173	.122				1973 ⁴	.228	.152			
Date ⁴	.215	.121				Date ⁴	.228	.149			
Date	.320	.114				Date	.364	.142			
<u>Black Crappie</u>											
Not Significant			Not Significant			Not Significant			1975	.277	.241
<u>Total Catch</u>											
Date ⁴	.105	.509	Date ⁴	.084	.368	1973 ⁴	.097	.546	1974	.225	.428
Date ²	.159	.500	Date ²	.189	.351	Date ⁴	.132	.543	1973	.387	.386
Date ²	.350	.446	Date ²	.335	.322	Date ²	.305	.493			
						Date ²	.419	.457			

TABLE 3. Pooled Estimates of the Variation among Replicate Nets

Species	Station			
	1	2	3	4
Carp	.280	.269	.336	.265
Silver Redhorse	.251	.302	.192	.390
Flat Bullhead	.266	.318	.239	.397
Bluegill	.222	.259	.215	.311
Largemouth Bass	.204	.231	.195	.277
Black Crappie	.203	.227	.216	.298
Total	.246	.287	.269	.356

TABLE 4. Coefficients of Variation for CPUE (Square Root Transformed) and Net Success Statistics

Species	Station			
	1	2	3	4
CPUE ($\sqrt{}$): Computed from average catch/net				
Carp	1.669	1.733	1.525	1.573
Silver Redhorse	1.999	1.580	2.739	0.772
Flat Bullhead	1.547	1.444	1.433	1.197
Bluegill	2.343	2.539	1.954	2.780
Largemouth Bass	2.575	2.277	2.332	2.259
Black Crappie	2.189	2.056	1.852	1.396
Total Catch	0.570	0.594	0.617	0.414

Net Success ($\sqrt{}$): Computed from number nets containing fish

Carp	0.502	0.524	0.454	0.464
Silver Redhorse	0.594	0.464	0.822	0.213
Flat Bullhead	0.455	0.422	0.420	0.344
Bluegill	0.703	0.766	0.579	0.833
Largemouth Bass	0.773	0.684	0.698	0.677
Black Crappie	0.654	0.612	0.547	0.404
Total Catch	0.165	0.164	0.179	0.128

TABLE 5. Coefficient of Variation for CPUE and Net Success¹

Species	CPUE	Net Success
Carp	0.509	0.263
Silver Redhorse	0.415	0.309
Flat Bullhead	0.383	0.237
Bluegill	1.045	0.788
Largemouth Bass	0.888	0.678
Black Crappie	0.440	0.268
Total Catch	0.162	0.071

¹Computed by dividing square root of mean square residual (from the factorial ANOVA's) by the grand mean.

TABLE 6. Significant Main Effects ($\alpha = 0.05$) and Interactions in Factorial ANOVA for CPUE (Square Root Transformed)

Species	Main Effects			Interaction		
	Date	Year	Station	Date-Year	Date-Station	Year-Station
Carp	X	X	X	X	X	X
Silver Redhorse	X	X	X			X
Flat Bullhead	X	X	X		X	X
Bluegill		X	X			
Largemouth Bass	X					
Black Crappie		X	X	X		X
Total	X	X	X	X	X	X

indicated similar population dynamics, as monitored by CPUE, occurring at those stations. However, the magnitude of the CPUE response may be different at those stations. Only for two species, carp and bluegill, were all station comparisons significantly correlated. Thus within the reservoir, temporal distribution of carp and bluegill was similar at all four stations. For the other species, temporal distribution in CPUE was different at one or more stations. For black crappie, pattern in CPUE across sampling time differed between stations 1 and 2; for silver redhorse, patterns at stations 3 and 4 were different. Largemouth bass CPUE for station 2 was not correlated with any other station, and for flat bullhead, station 4 differed from stations 1, 2 and 3.

Examination of spatial distribution for six species across four stations required a Chi-square contingency table. For each species and station, net success was summed over all sampling dates within a year (Table 7). Chi-square tests determined if species composition was homogeneous across sampling location; each year was analyzed separately. Results indicated that relative abundances of the six species were not the same at four stations in any of four years sampled. However, a pair-wise comparison of stations revealed no significant difference in patterns at stations 1 and 2. Further examination of the contingency table suggested that silver redhorse abundance at stations 3 and 4 were probably the primary contributors to the significant results. When silver redhorse data were removed from the analysis, relative abundances of the five species at four stations were the same in 1975 and 1976. In those years, species composition was similar at all four stations.

2.3.4 Precision

Another aspect of survey design evaluated was whether single or multi-species analysis would yield more precise results. Our measures of precision included pooled estimates of variance among replicates (s^2) (Table 3) as well as the mean square residual from regression and analysis of variance (Table 8). The species, ranked in order of increasing variation, were: largemouth bass, black crappie, bluegill, silver redhorse, carp and flat bullhead. Error estimates for total catch were similar to those for carp. Single species analysis would appear to yield more precise results than an analysis of total catch.

Correlation analysis was used to examine the possibility of combining data from several species. Data could be combined if CPUE for two or more species exhibited similar temporal distributions at the four stations. However, CPUE for only two species, silver redhorse and largemouth bass, were significantly correlated, and this correlation was negative. A negative correlation indicated that peaks in abundance for one species corresponded to low abundance levels for the other species. Combining data for these two species, therefore, would not reduce variation. A positive correlation existed between carp and silver redhorse abundance at all stations except station 3. And for other species, significant correlation existed for

TABLE 7. Chi-Square Contingency Tables for Net Success

Species	Station			
	1	2	3	4
1973 $\chi^2_{15} = 77.69$				
Carp	44	32	51	44
Silver Redhorse	26	46	10	73
Flat Bullhead	20	27	10	39
Bluegill	24	18	33	11
Largemouth Bass	9	5	5	13
Black Crappie	21	18	24	27
1974 $\chi^2_{15} = 64.86$				
Carp	32	24	33	34
Silver Redhorse	17	25	5	68
Flat Bullhead	18	22	27	34
Bluegill	7	9	19	9
Largemouth Bass	9	15	9	9
Black Crappie	12	11	17	31
1975 $\chi^2_{15} = 57.00$				
Carp	25	34	34	29
Silver Redhorse	15	30	2	58
Flat Bullhead	37	50	54	57
Bluegill	2	5	6	2
Largemouth Bass	19	19	18	20
Black Crappie	35	29	42	59
1976 $\chi^2_{15} = 47.00$				
Carp	30	32	29	34
Silver Redhorse	37	38	9	71
Flat Bullhead	66	57	53	51
Bluegill	1	0	1	1
Largemouth Bass	16	16	21	23
Black Crappie	24	22	33	47

TABLE 8. Mean Square Residual for CPUE from Regression Analysis and Factorial ANOVA

Species	Regression				ANOVA
	Station 1	Station 2	Station 3	Station 4	
Carp	.112	.076	.174	.058	.060
Silver Redhorse	.040	.047	.010	.064	.042
Flat Bullhead	.055	.073	.047	.081	.039
Bluegill	.034	.017	.040	.055	.029
Largemouth Bass	.013	.034	.021	.025	.015
Black Crappie	.040	.037	.067	.054	.027
Total					.076

particular species-station combinations. Results suggested that no natural groupings of species existed within the data.

2.3.5 Comparison of Analysis Methods

In evaluating the net success statistic, we first compared plots of net success versus sampling date with CPUE plots. Qualitatively, plots for both statistics were similar in pattern and magnitude (Appendix B). These results suggest that catch was fairly randomly distributed among ten nets.

One objective in evaluating the net success variable was to compare variation associated with this statistic with variation for CPUE. Comparable measures of variation (C.V.) were obtained by dividing the square root of the mean square residual from the factorial ANOVA's by the grand mean (Table 5). The resulting C.V.'s were smaller for net success than for CPUE. It also appeared that C.V.'s for net success and CPUE were more similar for non-abundant species (e.g., largemouth bass) than for abundant species (e.g., carp). This suggested that variation for non-abundant species was approximately equal for net success and CPUE. We examined this idea by comparing the C.V.'s for silver redhorse from stations 3 and 4. Only 2% of the silver redhorse were caught at station 3 compared to 70% at station 4; the catch at station 4 also represented 14% of the total catch. The ratio of net success C.V. to CPUE C.V. for station 3 was 1.18/1.59, while at station 4, the ratio was 0.14/0.39.

TABLE 9. Significant Main Effects ($\alpha = 0.05$) and Interactions in Factorial ANOVA for Net Success

Species	Main Effects			Interactions		
	Date	Year	Station	Date-Year	Date-Station	Year-Station
Carp	X	X		X	X	
Silver Redhorse	X	X	X			
Flat Bullhead	X	X	X		X	X
Bluegill		X				
Largemouth Bass	X					
Black Crappie		X	X	X		
Total	X		X	X		

A factorial ANOVA evaluated factors which significantly affected net success. As with data plots, the ANOVA results for net success were similar to those for CPUE. However, net success appeared to be less influenced by station effects (Table 9). Station effect was significant for only three species when net success was the measure of abundance, as compared to five species when CPUE was the response variable. Additionally, fewer station interactions with station were significant in the net success analysis compared to the CPUE analysis.

2.4 DISCUSSION

The goal of this and a previous report (McKenzie et. al. 1980) has been to assess the applicability of using fishery management techniques, specifically CPUE, to monitor fish populations near nuclear power plants. Data from riverine, ocean, large lake and, in this report, a reservoir site have been used to evaluate CPUE with regard to its ability to monitor population dynamics and to detect changes in population density. The ability of CPUE to fulfill these requirements is dependent on assumptions that 1) a single population of fish is being fished, 2) all members of the population have an equal chance of being caught, and 3) the unit of effort is proportional to the exploitation or fishing mortality rate. Achievement of equal probability of capture is primarily dependent on the spatial distribution of the population and the fishing effort.

In general, CPUE techniques have provided only qualitative information on population dynamics of resident fish populations. Of the six monitoring

surveys examined, only one (Pilgrim NPP, Cape Cod Bay) produced data which revealed a consistent seasonal trend (McKenzie et al. 1980). At this site, an otter trawl sampled a primarily benthic fish community (i.e., flounders and skates). The data from the survey at Lake Keowee is representative of the other five surveys. At these sites some peaks in abundance could be explained by general life history patterns, but they were generally accompanied by other peaks for which no explanation was available. Additionally, the number of peaks was not consistent from station to station, year to year, or, where multiple sampling gears were used, from sampling gear to sampling gear. The latter reflects the temporal and spatial variability in gear selectivity.

Limitations of CPUE techniques arise from an attempt to monitor a spatially and temporally mobile species with a level of effort fixed in both space and time. In these monitoring surveys, fishing effort is allocated to stations based on distance from a power plant site and on the ability of gear to sample the site. Of secondary consideration is the ability of gear to sample the fish community effectively, or the habitat type encompassed by sampling stations. A better test of applicability of CPUE techniques to fish monitoring surveys would be to employ an experimental design which more closely conformed to that used in fishery management. Such a design might depend upon a variable effort technique with sampling times concentrated on times when the fish are most abundant. Problems still exist with establishing control-treatment stations for evaluating fish populations (McKenzie et al. 1980). An additional study design consideration is to evaluate only selected fish species, i.e. not attempt to monitor several species with one spatial and temporal sampling effort.

Another aspect of CPUE technique evaluated was whether it was possible to detect a change in yearly population size. From analysis of variance procedures, estimates were derived for sampling error, $\hat{\sigma}^2$, and the variance component for between years, $\hat{\sigma}_Y^2$. A ratio $\hat{\sigma}^2/\hat{\sigma}_Y^2$ was calculated as a measure of variability of the monitoring technique relative to normal changes in fish abundance. Ratios for Lake Keowee, Lake Ontario and Cape Cod Bay surveys (Table 10) all indicate that sampling error was at least one order of magnitude greater than normal year-to-year variation. Large values for $\hat{\sigma}^2/\hat{\sigma}_Y^2$ ratio reflect the difficulty in detecting changes in fish abundance using CPUE techniques.

Ratios for individual species are in some cases lower than those for total catch and indicate that monitoring programs for selected species would be more likely to detect changes in CPUE. However, it is not clear what factors control this ratio. At Nine Mile Point, the most abundant species (alewife) had the lowest ratio, while at Lake Keowee, the smallest ratios were associated with the least and most abundance species (bluegill and flat bullhead).

TABLE 10. Estimates of Sampling Error ($\hat{\sigma}^2$) and Between Year Variance in Abundance ($\hat{\sigma}_y^2$) from the Analysis of Hierarchal Data. Analysis is Based on Square Root Transformed Values of CPUE Data from Nine Mile Point, Pilgrim and Oconee Nuclear Power Plants (NPP).

NPP	Data Set	$\hat{\sigma}^2$	$\hat{\sigma}_y^2$	$\hat{\sigma}^2/\hat{\sigma}_y^2$
Nine Mile Point	<u>Gillnet</u>			
	Total catch	1.387	0.067	20.7
	Alewife	0.956	0.150	6.4
	Spottail Shiner	1.128	0.023	49.0
	Rainbow Smelt	0.565	0.008	70.6
	White perch	0.639	0.019	33.6
	<u>Trawl</u>			
	Total catch	2.199	0.060	36.7
	Alewife	1.516	0.081	18.7
	Spottail Shiner	0.213	0.009	23.7
	Rainbow Smelt	1.058	0.035	30.2
	Threispine	0.141	0.0003	470.0
	Stickleback			
	<u>Seine</u>			
	Total catch	2.527	0.240	10.6
	Alewife	2.727	0.474	5.8
	Spottail Shiner	0.516	0.046	11.2
	White perch	0.784	0.012	65.3
Pilgrim	<u>Trawl</u>			
	Total catch	0.192	0.017	11.3
Oconee	<u>Gill</u>			
	Total catch	0.259	0.011	23.4
	Carp	0.083	0.013	6.3
	Silver Redhorse	0.255	0.013	20.3
	Flat Bullhead	0.087	0.022	3.9
	Bluegill	0.034	0.015	2.3
	Largemouth Bass	0.021	0.0016	13.6
	Black Crappie	0.057	0.012	4.8

Problems with interpreting CPUE data from monitoring surveys are in part related to study design. All these surveys were intended to evaluate a hypothesis of no impact resulting from operation of NPP. To test the no impact hypothesis, convention has been to set up stations near the NPP and at varying distances from it. As we have already discussed, considerations other than those relating to fish distribution are used in setting up these stations. Thus, at Pilgrim NPP where many of the species are distributed according to depth, the control station was of a shallower depth than the treatment station. At Lake Keowee it is uncertain what stations could be considered as controls. Station 4, located near reversible turbines, offered a unique habitat, and a plot of CPUE by station (Figure 2) reveals distinct differences in species abundance, especially between stations 3 and 4. If sampling stations are to serve as controls, it will be necessary to match habitat characteristics more closely. However, matching stations may not be feasible at specific sites.

In the investigation of CPUE, the binomial nature of the catch data was evident on many occasions. Sampling design at Lake Keowee provided data which could evaluate potential for using a statistic based on binomial probability. Results of a comparative analysis indicated that a net success statistic and CPUE were equal in their ability to describe seasonal population dynamics (Appendix B). Net success statistic was, however, less variable than CPUE and might therefore be able to detect a smaller yearly variation in population size. Additional comparisons between CPUE and net success are needed to develop a better understanding of the relationship between the two statistics.

Analysis of monitoring data from Lake Keowee confirmed findings from previous analyses of monitoring surveys at NPPs located on large lakes, rivers and coastal sites. CPUE techniques as applied to these monitoring programs do not provide data necessary to separate changes induced by operation of a NPP from naturally occurring changes. Utilization of CPUE techniques to detect changes in population abundance appears dependent upon development of sampling programs and statistical methodology capable of coping with transitory populations, changes in catchability and variability within and between years. Alternatively, programs with greatly increased sampling effort appear required to cope with the large degree of variability inherent in the resulting data.

2.5 ROLE OF MONITORING DATA IN SIMULATION MODELING

Simulation modeling is one of the tools that has been applied to prediction and assessment of power plant impacts. Swartzman et al. (1979) reviewed several such applications and found that simulation model results are dependent on mechanisms for which little if any quantitative basis exists. Subsequent efforts examined existing aquatic ecological simulation models, developed for objectives other than power plant impact assessment, for their usefulness at power plant sites (Swartzman et al. 1981). This latter effort included an application of modeling techniques to Oconee Nuclear Power Plant on Lake Keowee (Haar et al. 1981). General findings included a deficiency

FIGURE 2. Mean CPUE (Square Root Transformed) by Station for Six Fish Species in Lake Keowee

in existing data for components of the ecosystem that were biologically important but not sampled within the monitoring program. In addition, the CPUE data from the fish monitoring program were of little utility. This resulted primarily from the models inability to simulate spatial heterogeneity and limitations within the CPUE data. The lack of consistency among stations contributed to a lack of ability to use CPUE data within the modeling framework. Another factor was the need, in the model, to examine absolute density or abundance. With the relationship between CPUE and abundance being only qualitatively known and appearing to vary among sampling locations and times, no method of estimating abundance from CPUE data was available. Cove rotenoning data for Lake Keowee (Jenkins 1977) were more applicable, but still required untested assumptions about density and relationships in different habitats.

The data intensive nature of simulation modeling efforts make it appealing to use monitoring data to establish parameters for or test and validate power plant impact models. However, the limited spatial and temporal sampling frequency of most monitoring programs is incompatible with such uses (Thomas et al. 1981). An appropriate role for monitoring data for programs being considered in this report is to provide a qualitative comparison between model results and data on presence/absence of species, relative abundances among species, and magnitude of variability among stations, seasons and years.

3.0 SUMMARY OF PROJECT RESULTS

Task I efforts examined the available fisheries management techniques and assessed their potential application in a confirmatory monitoring program. Fisheries resource managers have developed several tools for assessing the fish population response to stress (exploitation) and were thought potentially useful for detecting nuclear power plant impacts. Results of Task I efforts are reported in McKenzie et al. (1979).

Task I results are for three categories of techniques; catch removal, population dynamics and nondestructive censuses. Population dynamics approaches were not pursued in spite of their initial attractiveness because of disadvantages in data requirements, statistical methodology, and interpretability of results. Two methods were recommended for further development; CPUE and Hydroacoustical techniques.

McKenzie et al. (1980) examined in detail the application of CPUE techniques in monitoring programs at riverine, large lake, and ocean sites. Examination of Oconee, a reservoir site, and included in this report, completes Task II efforts. The results of these efforts indicated that field experience does not support the assumptions underlying the CPUE approach. The assumption that CPUE indices can quantify reasonable population changes, at least within levels of sampling effort historically expended, does not appear to be supported by monitoring data. The "signal to noise ratio" and large CV values encountered in monitoring data indicated that relatively large changes may go undetected. CPUE evidence on population status was found to be dependent on season and time of sample collection. Generally, multiple sampling stations and gears presented conflicting pictures of population status. Thus, the interpretation of CPUE monitoring data must depend upon the experienced judgment of ecologists until better sampling and statistical methods can be developed that will quantify changes in catchability and variability among years.

3.0 SUMMARY OF PROJECT RESULTS

Task 1 efforts examined the available fisheries management techniques and assessed their potential application in a comprehensive monitoring program. Existing resource managers have developed several tools for assessing the fish population response to stress (expansion) and water treatment potential. Results of Task 1 efforts are reported in McKenzie et al. (1990).

Task 1 results are for three categories of techniques: catch removal, population dynamics and nondestructive censuses. Population dynamics approaches were not pursued in spite of their initial attractiveness because of disadvantages in data requirements, statistical methodology, and interpretability of results. Two methods were recommended for further development: CPUE and hydroacoustic techniques.

Mckenzie et al. (1990) examined in detail the application of CPUE techniques in monitoring progress at riverine, large lake, and ocean sites. Examination of Ocean, a reservoir site, and included in this report, comprises Task 1 efforts. The results of these efforts indicated that field experience does not support the assumptions underlying the CPUE approach. The assumption that CPUE indices can quantify reasonably population changes, at least within levels of sampling effort historically expended, does not appear to be supported by monitoring data. The "signal to noise ratio" and large CV values encountered in monitoring data and a lack of relatively large changes may go undetected. CPUE evidence on population status was found to be dependent on season and time of sample collection. Generally, multiple sampling stations and gears presented conflicting pictures of population status. Thus, the interpretation of CPUE monitoring data must depend upon the experienced judgment of ecologists until better sampling and statistical methods can be developed that will quantify changes in catchability and variability among years.

4.0 GUIDELINES FOR DESIGNING AND IMPLEMENTING DATA COLLECTION PROGRAMS

Accepting that the current state-of-the-art does not lead to quantitative monitoring programs does not imply that nothing should be done at Nuclear Power Plant sites. Material examined in this project and presented in reports suggests that guidelines can be established for fish and finfish monitoring programs. These guidelines are presented to aid in development of a monitoring program that is intended to continue after the "pre-operational, operational" monitoring program, a period of usually four or more years. Statistical techniques and results from this project may provide useful guidance in summarizing data from those programs. Development of state of the art monitoring programs can be implemented based on such evidence and general guidelines in this report.

A critical process in development of monitoring designs and sampling programs is establishment of objectives and impact hypotheses. Fritz et al. (1980) reviewed numerous impact assessments and came to the conclusion that hypothesis development was the single most important aspect. They describe a "hierarchy of hypotheses" relevant to monitoring programs. While some hypotheses cannot be tested or evaluated in a statistically rigorous framework, failure to establish hypotheses has contributed to unsatisfactory results on many programs. Fritz et al. (1980) present guidance in establishment of hypotheses for power plant impact monitoring programs that can be adapted to the present objectives.

A seemingly obvious, but apparently often unheeded, criterion for conducting a monitoring program is that of avoiding changes that adversely impact the interpretability of data (Gore et al. 1977). Changes in sampling gear, station location and sampling frequency generally reduce data usefulness. Such changes often result in changes in the data base that cannot be separated from changes in population status. Missing observations increases reliance on assumptions and robustness of statistical analysis techniques and may obscure relevant changes. Thus, as a general rule, a person responsible for monitoring at a site should resist changes in sampling strategies and endeavor to minimize missing observations. Selection of sampling gears and sites for ongoing confirmatory monitoring programs should consider previous sampling efforts and make changes after carefully reasoned examination of consequences.

The apparent interaction among sampling gears, habitat and species leads to a suggestion that a single gear be selected to monitor a species of concern. Multiple gear CPUE programs do not appear to be warranted as a general rule, but may be required by site specific circumstances. Selection of a sampling gear can be based on minimum CV for a habitat and species combination. Sampling gear that collects the widest range of ages and sizes is also recommended.

A difficult design decision is the number of sampling sites or stations. Results of previous data collection suggest that an initial assumption that

all sites will be different is warranted. Establishment of one or two stations seems likely to lead to a high probability of erroneous decisions due to high inherent variability. Limitations on sampling effort and a need for large numbers of observations at a site suggest that six or more stations is not generally advisable. Thus, three to five stations would appear to be reasonable.

Sampling frequency is another aspect a monitoring program designer must establish. Skalski and McKenzie (1982) have recommended that sampling frequency represent a balance between the need for multiple observations and serial correlations between sampling times. Another criterion for consideration is the relative information content contained by samples from different seasons. Such considerations can lead to establishment of critical time periods in the population and concentration of available sampling efforts during those times (Thomas and McKenzie 1979). Critical time periods could include spawning population abundance, young of the year (YOY) production, or periods of increased accessibility of the population to the sampling gear. These factors could lead to a sampling effort concentrated into one or two months rather than the currently more common approach of uniform sampling, e.g. once every month.

The applicability of collecting presence/absence data should be examined for a site-specific monitoring program. The results presented in this report suggest that little information is lost when this approach is taken. Sampling strategies could be considered where sampling effort is allocated to taking more samples with less effort per sample. Gill net sampling in lake Keowee is an example of this approach. Sampling effort could be allocated to sampling units (gill net sets) and fishing time such that approximately 50% of the nets catch the targeted species. Information to establish this approach will normally be contained in the available data base for a designer of an ongoing monitoring program.

5.0 GUIDELINES FOR DATA ANALYSIS AND INTERPRETATION

The primary objective of data analysis efforts should be to synthesize and extract information on population status contained in monitoring data. This objective can be met with data display and simplified descriptive statistics. Several different approaches were used on this project and represent recommended options for future programs. These methods included graphical techniques; means, variances and coefficients of variation; correlation coefficients; and limited application of hypothesis testing techniques, regression, ANOVA and Chi-square. Data display approaches are useful for demonstrating levels of variability among samples. Generally differences among samples, stations, months, and years will be apparent in such graphs.

We recommend that extensive hypothesis testing not be undertaken in connection with power plant monitoring CPUE data. This recommendation is based on two general realizations: 1) hypotheses that can be statistically tested generally do not provide meaningful information about fisheries impacts, and 2) hypotheses that would be meaningful cannot be tested. The hypothesis of equal means among several sampling stations is an example of a testable hypothesis for which results cannot be uniquely interpreted. In other words, rejection or acceptance of the null hypothesis can be the result of a multitude of factors, including differences in habitat, sampling efficiency, organism behavior, interactions among population densities at a station and environmental factors such as temperature or light, as well as power plant effects. At present no statistical method for separating natural from power plant induced variability exists. Assignment of statistically significant differences to power plant effects is unwarranted and not recommended. Testing a hypothesis of equal population density at stations prior to and over several years of power plant operation, while intuitively appealing, requires several assumptions that appear unsupportable. Interpretation of the temporal differences among years as an indication of power plant effects ignores or assumes constant all other factors. The power plant effects are confounded and inseparable from yearly differences in current sampling strategies.

As pointed out by Fritz et al. (1980), these limitations should not result in abandonment of statistics or hypothesis testing approaches. Rather, these limitations suggest caution and exercise of experienced judgment when analyzing and interpreting fish and shellfish monitoring data. We recommend that techniques utilized in McKenzie et al. (1979 and 1980), Metzger (1980) and this report be considered when addressing questions such as:

- selection of collection gear(s)
- number of sampling locations and frequency of collection
- variability among temporal and spatial components

- status of populations potentially influenced by power plant operations.

The primary objective of data analysis efforts should be to synthesize the existing information on population status contained in monitoring data. This objective can be met with data display and statistical descriptive statistics. Several different approaches were used on this project and the following are recommended options for future projects. These methods included: graphical techniques (mean, variance and coefficient of variation); correlation coefficients; and limited application of hypothesis testing (t-test, F-test, regression, ANOVA and chi-square). Data display approaches are useful for determining levels of variability among samples. Generally differences among samples, months, and years will be apparent in such graphs.

We recommend that extensive hypothesis testing not be undertaken in connection with power plant monitoring data. This recommendation is based on two general reasons: 1) hypotheses that can be statistically tested generally do not provide meaningful information about the biology, impacts, and 2) hypotheses that would be meaningful cannot be tested. The hypothesis of equal means among several sampling stations is an example of a testable hypothesis for which results cannot be meaningfully interpreted. In other words, rejection or acceptance of the null hypothesis can be the result of a multitude of factors, and minor differences in habitat, sampling effort, seasonal behavior, hydrologic and wind conditions, density of a species, and environmental factors such as temperature or light as well as power plant effects. At present no statistical method for separating natural from power plant induced variability exists. Assignment of statistically significant differences to power plant effects is unwarranted and not recommended. Testing a hypothesis of equal population density at stations prior to and over several years of power plant operation will be similarly inappropriate, requiring several assumptions that appear unwarranted. Interpretation of the temporal differences among waters as an indication of power plant effects requires an assumed constant of other factors. The power plant effects are confounded and inseparable from yearly differences in currents, sampling strategies.

As pointed out by Fritts et al. (1980), these limitations should not result in abandonment of studies on hypotheses testing procedures. Rather, these limitations suggest caution and exercise of experienced judgment when analyzing and interpreting fish and wildlife monitoring data. Recommendations outlined in Fritts et al. (1979 and 1980), Heller (1980), and this report be considered when addressing questions such as:

- selection of collection gear(s)
- number of sampling locations and frequency of collection
- variability among temporal and spatial components

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APPENDIX A

COMMON AND SCIENTIFIC NAMES OF FISHES REPORTED
FROM KEOWEE RESERVOIR, JUNE, 1979

APPENDIX A

COMMON AND SCIENTIFIC NAMES OF FISHES REPORTED FROM KEOWEE RESERVOIR, JUNE, 1979

Rainbow trout	<u>Salmo gairdneri</u> Richardson
Brown trout	<u>Salmo trutta</u> Linnaeus
Chain pickerel	<u>Esox niger</u> Lesueur
Carp	<u>Cyprinus carpio</u> Linnaeus
Golden shiner	<u>Notemigonus crysoleucas</u> (Mitchill)
Quillback	<u>Carpiodes cyprinus</u> (Lesueur)
Northern hog sucker	<u>Hypentelium nigricans</u> (Lesueur)
Spotted sucker	<u>Minytrema melanops</u> (Rafinesque)
Silver redhorse	<u>Moxostoma anisurum</u> (Rafinesque)
Smallfin redhorse	<u>Moxostoma robustum</u> (Cope)
Snail bullhead	<u>Ictalurus brunneus</u> (Jordan)
White catfish	<u>Ictalurus catus</u> (Linnaeus)
Brown bullhead	<u>Ictalurus nebulosus</u> (Lesueur)
Flat bullhead	<u>Ictalurus platycephalus</u> (Girard)
Channel catfish	<u>Ictalurus pumctatus</u> (Rafinesque)
White bass	<u>Morone chrysops</u> (Rafinesque)
Hybrid bass (striped bass x white bass)	<u>Morone</u> sp.
Green sunfish	<u>Lepomis cyanellus</u> (Rafinesque)
Warmouth	<u>Lepomis gulosus</u> (Cuvier)
Bluegill	<u>Lepomis macrochirus</u> Rafinesque
Redear Sunfish	<u>Lepomis microlophus</u> (Gunther)
Redeye bass	<u>Micropterus coosae</u> Hubbs and Bailey
Largemouth bass	<u>Micropterus salmoides</u> (Lacepede)
White crappie	<u>Pomoxis nigromaculatus</u> (Lesueur)
Yellow perch	<u>Perca flavescens</u> (Mitchill)
Walleye	<u>Stizostedion vitreum vitreum</u> (Mitchill)

APPENDIX A

COMMON AND SCIENTIFIC NAMES OF FISHES REPORTED FROM KEOWEE RESERVOIR, JUNE, 1979

Rainbow trout	<i>Salmo gairdneri</i> Richardson
Brown trout	<i>Salmo trutta</i> Linnaeus
Chain pickerel	<i>Esox niger</i> Lesueur
Carp	<i>Cyprinus carpio</i> Linnaeus
Golden shiner	<i>Notemystus crysoleucas</i> (Mitchill)
Gulf herring	<i>Clupea cyanea</i> (Lesueur)
Northern hog sucker	<i>Aplodinotus grunniens</i> (Lesueur)
Spotted sucker	<i>Moxostoma valenciennesi</i> (Rafinesque)
Silver shiner	<i>Moxostoma valenciennesi</i> (Rafinesque)
Smallmouth bass	<i>Micropterus dolomieu</i> (Leach)
Shad	<i>Alosa sapidissima</i> (Wilson)
White catfish	<i>Ictalurus punctatus</i> (Rafinesque)
Brown bullhead	<i>Ictalurus nebulosus</i> (Lesueur)
Flat bullhead	<i>Ictalurus platycephalus</i> (Garrod)
Channel catfish	<i>Ictalurus punctatus</i> (Rafinesque)
White bass	<i>Morone chrysops</i> (Rafinesque)
Hybrid bass (striped bass x white bass)	<i>Morone</i> sp.
Green sunfish	<i>Lepomis cyanellus</i> (Rafinesque)
Wormmouth	<i>Lepomis gibbosus</i> (Lauener)
Bluegill	<i>Lepomis macrochirus</i> Rafinesque
Yellow perch	<i>Perca flavescens</i> (Mitchill)
Rock bass	<i>Ambloplites rupestris</i> (Lacépède)
Largemouth bass	<i>Micropterus salmoides</i> (Lacépède)
White crappie	<i>Crappie</i> sp.
Yellow perch	<i>Perca flavescens</i> (Mitchill)
Walleye	<i>Stizostedion vitreum</i> (Mitchill)

APPENDIX B

PLOTS OF CPUE (SQUARE ROOT TRANSFORMED) AND NET SUCCESS VERSUS
SAMPLING DATE FOR EACH SPECIES AND SAMPLING LOCATION COMBINATION

FIGURE B.1. Net Success and CPUE for Largemouth Bass, Station 1

FIGURE B.2. Net Success and CPUE for Largemouth Bass, Station 2

FIGURE B.3. Net Success and CPUE for Largemouth Bass, Station 3

FIGURE B.4. Net Success and CPUE for Largemouth Bass, Station 4

FIGURE B.5. Net Success and CPUE for Bluegill, Station 1

FIGURE B.6. Net Success and CPUE for Bluegill, Station 2

FIGURE B.7. Net Success and CPUE for Bluegill, Station 3

FIGURE B.8. Net Success and CPUE for Bluegill, Station 4

FIGURE B.9. Net Success and CPUE for Carp, Station 1

FIGURE B.10. Net Success and CPUE for Carp, Station 2

FIGURE B.11. Net Success and CPUE for Carp, Station 3

FIGURE B.12. Net Success and CPUE for Carp, Station 4

FIGURE B.13. Net Success and CPUE for Flat Bullhead, Station 1

FIGURE B.14. Net Success and CPUE for Flat Bullhead, Station 2

FIGURE B.15. Net Success and CPUE for Flat Bullhead, Station 3

FIGURE B.16. Net Success and CPUE for Flat Bullhead, Station 4

FIGURE B.17. Net Success and CPUE for Black Crappie, Station 1

FIGURE B.18. Net Success and CPUE for Black Crappie, Station 2

FIGURE B.19. Net Success and CPUE for Black Crappie, Station 3

FIGURE B.20. Net Success and CPUE for Black Crappie, Station 4

FIGURE B.21. Net Success and CPUE for Silver Redhorse, Station 1

FIGURE B.22. Net Success and CPUE for Silver Redhorse, Station 2

FIGURE B.23. Net Success and CPUE for Silver Redhorse, Station 3

FIGURE B.24. Net Success and CPUE for Silver Redhorse, Station 4

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