ASSESSING THE IMPACT OF POWER PLANTS ON STRIPED BASS (MORONE SAXATILIS) IN THE SACRAMENTO-SAN JOAQUIN DELTA

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ABSTRACT.

A strategy for assessing the impact of power plants on striped bass (*Morone saxatilis*) of the Sacramento-San Joaquin river system is presented. The Strategy is divided into three assessment categories: 1) Direct involvement, 2) Short-term response, and 3) Long-term population consequences. Measures of impact within each of these categories are discussed with reference to theoretical development and data requirements. The end product of this strategy is a systems approach to impact assessment which places the role of the power plants in perspective to the behavior of the entire system.

Evaluating the impact of cooling water intake structures on aquatic communities has become an area of extensive research since the passage of the 1972 amendments to the Federal Water Pollution Control Act (P.L. 92-500 Section 216(b)). To meet the requirements of section 316(b), the Pacific Gas and Electric Company (PG&E) has contracted Ecological Analysts (EA) to evaluate potential impact of their existing and proposed power plants on the aquatic community of the Sacramento-San Joaquin Delta.

Together PG&E and EA have initiated rigorous sampling programs and assessment methods to answer such questions as whether impacts of power plants are high enough to require alternate cooling water technology. We must try to understand all the factors affecting a community before we can discuss specific effects of existing power plants or the effects of adding additional power plants to the system.

This report presents a strategy for assessing impact of power plants which can be applied not only to the Sacramento-San Joaquin estuary but to a number of aquatic systems. The assessment strategy will be illustrated using striped bass (*Morone saxatilis*) of the Sacramento-San Joaquin delta as an example.

The Sacramento-San Joaquin river system forms a large tidal estuary (Figure 1). Inflows into the estuary are largely controlled by flows from upstream reservoirs. The magnitude of inflow into Suisun Bay in turn controls the location of the oceanic salt front. In high flow years, the salt from remains in the vicinity of San Pablo Bay, while in low-flow years, the salt front can migrate up to and beyond the confluence of the Sacramento-San Joaquin rivers.

The estuary is used by striped bass for spawning and as a nursery ground. Adults spawn in the upper tributaries of the Sacramento and San Joaquin rivers, depositing their eggs within the water column. As the eggs drift downstream they develop into larval stages which, in turn, give rise to juvenile stages. Both larvae and juveniles remain in fresh water, using the delta as a nursery area. Once juveniles reach the yearling stage they migrate to salt water, returning to the delta as spawning adults.

The number of striped bass produced in the delta in a single year is highly variable. Researchers at the California Department of Fish and Game have shown a strong positive relationship between water inflow and year-class strength, suggesting that year-class strength

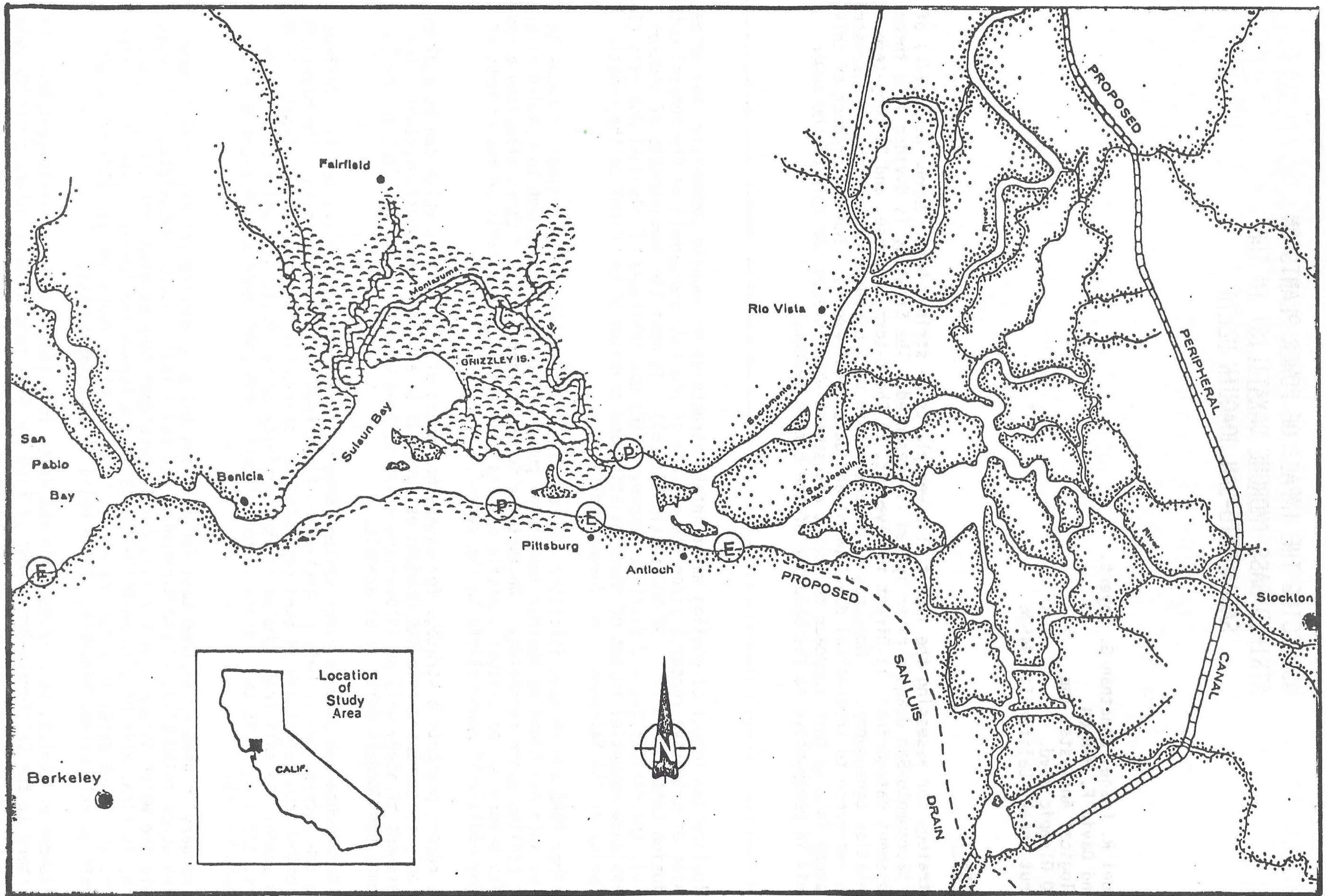

FIGURE 1. Map of the Sacramento - San Joaquin delta showing locations of existing and proposed power plants.

may be determined by flow (Stevens 1977). Year-class strength may also be affected by specific point losses in the delta system. These points include the two existing power plants owned by PG&E, two water export stations at the southern end of the delta, the Contra Costa Canal, and numerous irrigation losses scattered throughout the delta.

The impact assessment strategy developed by EA is based on a logical sequence of problem solving steps which have been grouped into three major assessment categories: 1) Direct involvement, 2) Short-term response, and 3) Long-term population consequencts. The strategy has been designed to specifically address the impact of power plant induced losses in the striped bass population. It additionally places these losses in perspective to losses associated with other sources and the inherent environmental variability.

Direct Involvement:

The assessment category of direct involvement is concerned with evaluating the magnitude of the immediate impact of the power plants. The ultimate measure of impact in this category is the number of striped bass cropped for each age class affected. In addition, numbers of striped bass cropped for various life stages within the young-og-the-year age class is determined. Estimates of numbers cropped are determined by measuring entrainment and impingement abundance, and entrainment and impingement survival.

At each delta power plant, water samples are collected over a 24-hour period twice a week during entrainment season. Striped bass in the water samples are counted and measured. Entrainment densities are calculated and combined with power plant flow rates to determine the total number of striped bass entrained.

During the entrainment season, striped bass are collected for survival studies using larval tables at both intake and discharge stations. The striped bass are held in a latent effects laboratory to determine long-term survival. Survival curves based on duration of exposure, delta t, and ambient temperature are then constructed. Entrainment cropping estimates are calculated by multiplying entrainment abundance and entrainment survival estimates.

Similar studies are conducted at the power plant's intake screens over 24-hour periods to determine impingement cropping. After each screen wash the impingement striped bass are counted and measured. All fish that are alive after impingement are held four (4) days to determine long-term impingement survival. Impingement abundance and survival are combined to determine impingement cropping.

The entrainment cropping estimates and the impingement cropping estimates are combined to produce an estimate of total cropping. Total cropping due to entrainment and impingement then gives us an estimate of the direct losses at the power plant.

Short-term Response:

The methods contained in the short-term response assessment category are designed to translate the estimate of total number cropped into more meaningful measures of impact. The measures included in this category are: 1) equivalent adults lost, and 2) percentage reduction in the young-of-the-year population. These measures are labeled short-term because they do not consider the future loss to the reproductive capacity of the adult striped bass population as a whole.

Equivalent adults is a measure of the number of adults that would have resulted from the entrained and impinged striped bass. This estimate is useful in that it allows for comparison of numbers cropped between power plants and the striped bass sports fishery.

To determine equivalent adults lost one must know the survivorship from the stage of impact to adults. A simplistic approach is to consider a population in equilibrium such that each adult female produces a sufficient number of eggs in her lifetime to replace herself and one adult male. Survival from egg to adult is then estimated as twice the reciprocal of lifetime fecundity. It has been shown, however, that this approach may underestimate equivalent adults lost because of the high variability in survival for early life stages (Goodyear 1978). A better approach is to use all available data on the survival of the species individual life stages. If survival of each life stage can be estimated separately, taking into account all influencing factors, then a more accurate estimate of equivalent adults lost can be calculated. This method does, however, require a much larger data base. Although the equivalent adults measurement of impact is useful, it does not give an estimate of the relative loss to the population.

A second measurement of short-term response is the percentage reduction in young-of-the-year striped bass caused by power plant operation. Percentage reduction is calculated to place cropping estimates in perspective to the population size of the young-of-the-year class. This requires a comprehensive survey of abundances for each of a number of stages comprising the young-of-the-year class. This has been accomplished by conducting weekly surveys for all portions of the system which contain individuals of this class. From this data, a value for the numbers of organisms surviving the age class is computed. Then, using the estimates of numbers cropped, a second and higher value for the numbers of organisms surviving the age class is computed. This second value is the predicted numbers which would have survived in the absence of power plant related mortality. The final estimate is then the percentage reduction in the numbers surviving with power plant operation.

Long-Term Population Consequences:

The long-term consequences of entrainment and impingment losses may be manifested in a future loss to the reproductive capacity of the striped bass population. The measurement of this loss becomes somewhat more difficult because one must deal with future generations not yet measured.

Two population models which have commonly been used to evaluate impact of power plants on striped bass are the Leslie matrix (Leslie 1945, 1948) and the spawner-recruit models (Ricker 1975).

The basic Leslie matrix model is often used to express the "worst case" reduction in adult population levels. In its most simple form, the leslie matrix assumes density-independent mortality (i.e., no compensation). A projection matrix consisting of age-specific fecundity levels in the first row, age-specific survival rates on the sub-diagonal and zeros elsewhere is constructed. Changes in survivorship at any life stage due to power plant operation can be incorporated into this matrix. The product of the matrix and an age distribution vector at time t, is a new age distribution vector at time t + dt, where dt is usually taken as one year. The multiplication is repeated for the number of years the power plant will operate. The population response to various sustained levels of reduction in survival can then be determined.

The second approach, the spawner-recruit model, assumes density-independent and density-dependent mechanisms act together to regulate the population. The relationship between spawners and recruits produced by those spawners is called a spawner-recruit model. Data required to fit this model are long-term (20 years) indices of spawner abundances, which in the case of the striped bass, may be derived from sport catch-per-effort statistics. A curve is fitted to the indices of spawner and recruit abundance. The number of spawners required to maintain the population in equilibrium can be calculated from this curve. Within the framework of this model, if a fishery (a power plant) is imposed on the population, it will respond by seeking a new equilibrium level. Power plant impact is measured as percentage reduciton in equilibrium levels of the spawners.

The spawner-recruit and Leslie matrix models both have shortcomings. In their most simple form, they describe the dynamics of a population which is unaffected by natural and man-induced flucuations in the environment. Both models are deterministic in nature, and each involves tenuous assumptions regarding the compensatory abilities of the population. In order to overcome the inadequacies of these simple population models, the assessment strategy takes a systems approach. The major thrust of this approach is to investigate the role played by the power plants in reference to the behavior of the entire system. The result is an assessment which places the impact of the power plants in perspective to all other properties of the system, natural and man-made, which significantly affect striped bass. This approach is not a simple one. Successful application of the method is dependent upon detail investigations of all available data in search of means by which to represent the dynamics of the system in the most simple yet realistic fashion.

The strategy divides the investigation into three parts: 1) examination of available data in search of evidence for compensatory mechanisms operating in the Sacramento San Joaquin striped bass population, 2) explanation o- variation observed in year-class strength of striped bass, and 3) determination of factors affecting losses at power plants and alternate points of water withdrawal.

An examination of the compensatory mechanisms operating in the Sacramento-San Joaquin bass population is imperative to determine whether the adult population model should involve a Leslie matrix approach, a spawner-recruit approach, or some combination of the two. The assessment strategy looks at a number of compensatory mechanisms. These include the relationships between spawners and progeny, growth rate and year-class strength, survival and density, and fecundity and age of maturity. An understanding of these mechanisms should lead to incorporation of some form of compensation into the adult models.

The effect of enviornmental variation on year-class strength must also be examined. As mentioned earlier, the California Department of Fish and Game has shown that there is a strong positive correlation between delta outflow and abundance of young-of-the-year striped bass. The systems approach strategy uses statistical models to examine not only flow rates but other factors such as export rates, adult population size, power plant operations, etc., to determine the important factors regulating the young-of-the-year population size.

The third area of investigation centers on the factors influencing striped bass mortality at specific sites of water withdrawal. Water withdrawal sites of primary consideration are power plants (existing and proposed), water export stations, and irrigation canals. For each site, a detailed examination of the factors influencing mortality (natural and man-induced) is conducted. The product of this effort is a set of statistical models capable of predicting mortality at the various sites for a given set of influencing factors.

SUMMARY

Assessing the impact of power plants on a population of fish which are part of a system as complex as the Sacramento-San Joaquin delta is not an easy task. Monitoring entrainment and impingement at power plants only begins to solve the problem. To properly address the issue one must evaluate the power plants in light of the role they play as a component of a larger system. Successful implementation of this approach is dependent upon a carefully designed strategy for assessing impact. Extensive sampling and rigorous methods of assessment are integral parts of this strategy. The strategy should be logical and systematic, beginning with an estimation of direct losses at power plants and culminating with long-term population consequences. Only after the development of a strategy of this type, can intelligent decisions be made regarding power plant intake structure design and operation.

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