DRAFT DISCUSSION PAPER

ECOSYSTEM HEALTH OF THE BAY-DELTA SYSTEM

I. INTRODUCTION

Management of Bay-Delta environmental resources in the past has often been focused on specific fish populations (e.g. striped bass) and habitat types (e.g. wetlands, tidal marsh). Water quality standards, such as those in D-1485 in 1978, prescribed Delta inflow, outflow, and export limits to protect striped bass. Despite improvements in some Bay-Delta conditions, such past management efforts as D-1485 failed to stem long-term declining patterns in key populations and communities. Recent efforts to manage the Bay-Delta system and specifically the December 15th (1994) Accord, the subsequent Draft Water Quality Control Plan, and associated Interim Water Quality Standards promote a more holistic or ecosystem management approach to solving the Bay/Delta problems.

Many of us have heard the statement that "the Bay-Delta system is broken and needs to be fixed." The statement is generally in reference to the unhealthy state of the Bay-Delta system as represented by a variety of situations including reductions in fish populations thought to be caused by poor habitat conditions, poor plankton production, and the direct loss of young fish to water supply diversions. Many believe this state of affairs is attributable to diversion of fresh water for water supply, the discharge of nutrients and toxic substances in wastewater returned to the system, the introduction of non-native species, the overharvest of fish in commercial and sport fisheries, and the loss and degradation of habitat.

The purpose of this discussion paper is to review the basic concepts and definitions embodied in the phrase "ecosystem health". Such concepts will be useful in understanding environmental problems and developing solutions to problems in the CALFED Bay-Delta Program. Basic concepts and definitions of ecosystem health in the context of the Bay-Delta system are presented in the following discussions.

To solve the problems associated with ecosystem quality in the Bay/Delta system, the CALFED Bay-Delta Program intends to develop a strategy for addressing the problem from an ecosystem health approach. The ecosystem health perspective draws upon parallels from human health and risk assessment. Parallels include:

- viewing the problems of the Bay-Delta system in the context of disease,
- looking for symptoms to provide insight to the cause of the disease,
- developing potential treatment programs or programs to restore the health,
- developing tools to view the "pulse" or "blood pressure" of the system,

- determining the consequences to the system if the disease is left untreated,
- analyzing the costs and benefits of treatment to correct the problem,
- defining health problems and the array of possible treatments,
- assessing whether we must know the exact extent of the disease and cause before we resort to treatments,
- determining potential arrays of treatments to reduce the extent of potential damage from disease, and
- adjusting treatments based on the response of the system's vital signs.

II. BASIC DEFINITIONS

In order to provide a shared understanding of terms that will be continually used throughout the CALFED Bay/Delta problem solving process, the following definitions and general explanations are provided.

A. ECOLOGY

Ecology is the study of the interrelationships of organisms with their environment.

B. ECOSYSTEM

Ecosystem is another term for nature, or the combination of living organisms and physical and chemical components of the environment that function as a unit in nature.

C. ECOSYSTEM STRUCTURE AND FUNCTION

The **structure** of an ecosystem is its basic biological, physical, and chemical composition. The biological structure is the species, numbers, life history, and location of organisms and populations in time and space. The physical and chemical structure includes the quantity, quality and distribution of water, nutrients, sediments, chemicals, water temperature, salinity, light, etc. A system like the Bay-Delta system has an incredibly complex structure with many species and a wide range of physical and chemical characteristics that varies substantially by season and over years. The ability of a system to adapt or evolve over time to deal with natural variation is a unique function of ecosystems. The Bay-Delta system is particularly complex considering its varied channel structure, urbanized character, introduced species of plants and animals, and variable inflow of fresh water. Substantial research and monitoring in the Bay-Delta system has focused on defining and understanding this structure.

Ecosystem **function** is related to the rate of energy flow through an ecosystem. While structure can be characterized as the building blocks of a system, the **function** is the interactions between the structural components that make the system operate. In more simple terms, function is what makes an ecosystem work. A simple list of species and their distribution and abundance is not adequate for understanding how an ecosystem works. A study of function in combination with structure is necessary. The function of the Bay-Delta system is itself of fundamental importance: it functions as a nursery ground for many estuarine, freshwater, and anadromous fish. Ecological processes concentrate food supplies and create salinity, temperature, and flow conditions that optimize growth and survival of young fish and invertebrates such as zooplankton, sediment dwelling invertebrates, shrimp, and crabs.

In the Bay-Delta system, understanding the relationship between structure and function is very important to understanding the underlying cause and effect of ecological problems and developing solutions. Ecological processes in the Bay-Delta system that are important include those that control the food web, such as what drives plant production and how plant production is converted to fish production. **Ecosystem function is the critical element of ecosystem health.** The state of key Bay-Delta system processes, such as spring plankton blooms, is potentially a valuable indicator of ecosystem health.

D. ECOSYSTEM HEALTH

A healthy ecosystem is one which is capable of maintaining a stable condition, is able to repair or correct itself when perturbed, and needs minimal external support for management. On the contrary, an unhealthy ecosystem is characterized by reductions in numbers and diversity of aquatic ecosystem types, loss or decrease of large long-lived species, and an increase in short-lived opportunistic species.

The state of health of a system is based on benchmarks of ecosystem structure and function components. Individual structure or function components may have values ranging from unhealthy to healthy. Benchmarks are values placed by scientists, resource managers, or society and state of health may become a value judgement on the part of these same groups. The concept of ecosystem health is not unlike the human health context. The ultimate goal of resource managers in the Bay-Delta system should be to diagnose and treat ecological health problems using measures that reflect the health of the system much as body temperature, pulse, and blood pressure are used for human health assessment. In recent years Bay-Delta resource managers have focused less on arguing about how sick the "patient" is, and are beginning to concentrate more on treatment.

The ecosystem quality objectives produced by the CALFED Bay-Delta Program are the first step for defining ecosystem health. It is critical to the process to identify a set of objectives, and then performance measures, to capture and convey the essence of ecosystem health.

E. POPULATION

A population is several individuals of one species that live together as one cohesive and self-sustaining group.

F. POPULATION HEALTH

Population health generally refers to the capacity of a group of individuals of a species to maintain itself within its range. The population's ability to withstand reasonable levels of harvest is one measure of a population's health. Other measures are the extent to which a population fills its available habitat and the extent to which the population meets societal goals.

G. HABITAT

Habitat is the physical, chemical, and biological characteristics of the place where organisms live. It includes physical attributes such as spawning gravel , but also includes attributes such as sufficient flow and water quality. The actual physical attributes can be present, but unless they are functioning properly, they may be ineffective. Habitat is ecosystem structure and function tied into one. The Bay-Delta system has many different types of habitats, which contribute to its ecological complexity and diversity of plants and animals. Key factors in estuarine habitat include hydrologic characteristics such as tides, fresh water inflow patterns, and flow distribution.

H. ECOLOGICAL INDICATORS

Ecological indicators are measures of the state of ecosystem structure or function. Indicators can also be used to evaluate the effectiveness of management actions. In the Bay-Delta system, very basic indicators include salinity, flow, and the presence or absence of specific organisms.

I. ECOSYSTEM HEALTH INDICATORS

Ecosystem health indicators are a subgroup of ecological indicators that represent the state or health of an ecosystem. There are many ecological indicators that can be used to measure the state of health of the Bay-Delta system. These indicators can measure structure and function at various ecosystem levels including species, populations, communities, and landscapes. The index of abundance of striped bass has long been an important measure of the ability of the system to produce young fish. Water quality standards are often indicators of the limit of acceptable levels of certain water quality parameters. Other indicators that provide insight on health include the extent of spring algae blooms; the aerial extent of certain types of habitat; the abundance of certain estuarine invertebrates important in the food web of young fish; the abundance of other fish species, such as delta smelt and Sacramento splittail; and the levels of toxins in the tissues of fish and shellfish. Arrays of indicators provide a wider view of ecosystem health. Specific indicators, such as the status of a threatened or endangered species, can target specific concerns. Abundance of key life stages of fish species provides insights into the health of their populations and the ecosystem as a whole. Physical measures, such as the percent of Delta inflow diverted for water supply or the position of the upstream extent of the salt intrusion (often described as X2 factor) in the system, are often considered key indicators of the health of the Bay-Delta system.

J. ECOSYSTEM MANAGEMENT APPROACH

In recent years there has been a movement to adopt an ecosystem approach to managing the nation's environmental resources. Under this ecosystem management approach, forests, rivers, lakes, rangelands, and estuaries are being managed using a holistic approach that addresses management of more than just single or several key species. An ecosystem approach to managing environmental resources deals with the entire living and nonliving components of an ecosystem and how the components interact, and includes management for diversity of not only species, but also habitat and hydrologic conditions. In other words, it requires examining, understanding and considering both structural and functional ecosystem components. Such an approach has limitations: key among these being the need for extensive information on structure and function of the ecosystem. The approach also has problems of scale and depth of complexity which can severely limit its applicability.

K. POPULATION APPROACH

A population approach to managing resources focuses on managing for abundance, distribution, or specific population parameters such as growth or reproduction. Anadromous fish (salmon, steelhead, American shad, striped bass, and sturgeon) restoration in the Central Valley focuses on adult production goals. One of the goals of the State Board's Decision 1485 in 1978 was to manage flows to provide a specific average annual production level of young striped bass in the estuary.

L. HABITAT APPROACH

A habitat approach is a subset of the ecosystem approach. A habitat approach to managing environmental resources focuses on physical, chemical, and biological elements of an ecosystem important to the production and well-being of key species. Habitat includes physical aspects, such as spawning gravel for salmon, and physical and chemical aspects related to the timing and quantity of freshwater flow. While a habitat approach appears to focus primarily on the building blocks or structural aspects of the ecosystem, it is the functioning of the habitat to support sustainable levels of populations and communities which is critical to determining success. Another aspect concerning habitat is the idea of connectivity; providing more connections between comparable habitats and less fragmentation.

M. ADAPTIVE MANAGEMENT

Adaptive management is a proactive incremental implementation of actions and responses to managing environmental resources. A good example of adaptive management is managing salmon populations in coastal rivers. Fisheries managers adjust harvest levels from year to year based on harvest and habitat conditions. Management strategies are adjusted based on results of specific actions. With more and more experience, managers can fine-tune their resource options to optimize their management options based on results of specific actions. In the Bay-Delta system, adaptive management can take many forms, such as interim water quality standards. If standards are ineffective at meeting goals, they can be adjusted and further refined. The benefits of an adaptive management program is that it allows resource managers to make decisions and implement recommendations based on the best defensible science available at that time. There is often a lack of substantial information on ecosystem structure and function which may hinder environmental management decisions. This scientific uncertainty associated with managing natural resources can be accomodated using an adaptive management approach. It allows the implementation of monitoring and research programs designed to test the assumptions, upon which the recommendations are based, and "fine tune" management options as needed to meet the specified objectives.

III. ECOSYSTEM HEALTH APPROACH FOR BAY-DELTA SYSTEM

The application of an ecosystem health approach to the Bay-Delta problems and need for solutions offers the advantage of addressing the problems (diseases) from a treatment and adaptive management perspective. After several decades of trying to define the extent of the problem and causes, focus now is on treatment and response (adaptive management). The ecosystem health approach for the Bay/Delta has been described by several entities. The scientific community has recognized the need for defining goals and indicators to restore the ecosystem health of the Bay-Delta system. Several workshops have recently been conducted to address these issues.

A basic ecosystem health approach was discussed at a recent workshop sponsored by a variety of agencies and stakeholders and is outlined by Levy et al.[1].. This workshop, entitled "Restoration of the San Francisco Bay-Delta Ecosystem: Choosing Indicators of Ecological Integrity", was convened to define and develop the concept of indicators for use by the CALFED Bay-Delta Program. This approach advocates that new, more direct measures of the important and desirable structure and function of the Bay-Delta ecosystem may be necessary to ensure resources are protected while human use of the Bay-Delta system continues. A four-step process is suggested:

Step 1: Define health in an operational way.
Define important structure and functional elements of the Bay-Delta ecosystem. Define the desired state of these elements.

Step 2: Select indicators of health
From among the structural and functional elements of the ecosystem, select a suite of indicators that provide a picture of the health of the Bay-Delta system. Indicators should be selected to reveal potential disruption as a result of stressors. Stressors should be listed, likely responses to stresses assessed, and indicators identified which best measure effects of stresses. Indicators (1) should be sensitive to provide early warning, (2) should have wide geographic applicability, (3) should provide a continuous measure of assessment over a wide range of stress, (4) should be cost-effective, (5) should be ecologically meaningful, (6) should be relevant to societal concerns, (7) should have benign measurement effect, (8) should be easily interpretable, (9) should be readily measurable and quantifiable, and (10) should have a long historical record and pattern established.

Step 3: Identify target levels of indicators that define health or lack of health.
A range of target values or benchmarks from unhealthy to healthy should be developed for each indicator. Comparison with some reference system is preferable. Target levels for a health state should be established; targets need not be the pristine state.

Step 4: Develop a monitoring system to provide feedback.
A monitoring program that provides measures of indicator levels should be implemented to provide feedback and potential for adaptive management.

K. Levy, R. Fujita, and T. Young. 1995. Designing restoration of the San Francisco Bay Delta-River Ecosystem-- A framework for developing ecological indicators and thresholds. Discussion paper for the workshop "Restoration of the San Francisco Bay-Delta-river Ecosystem: Choosing Indicators of Ecological Integrity". Environmental Defense Fund. Oakland, California.

Another workshop, "Goals for Restoring a Healthy Ecosystem", was held to discuss goals for restoring a healthy ecosystem. In a paper prepared for that workshop, Kimmerer[2] suggests a number of health indicators and performance measures for the Bay-Delta system. He defines a "healthy" Bay-Delta system as one in which a full complement of estuarine species flourishes with thriving, diverse wetlands; clear water; plenty of oxygen; numerous fish of many species and a variety of sizes; and thriving commercial and recreational fisheries supported by natural production. The summary of the workshop provided a partial list of health goals for the system including the following:

- restore populations of indigenous species;
- maintain populations of fish and waterfowl that can be eaten safely;
- provide anglers with a reasonable chance of catching sport fish;
- increase naturally reproducing populations of anadromous fish;
- maintain sediment contamination at least below levels seen in 1950;
- prevent conditions that would result in water column anoxia, including harmful and nuisance algal blooms;
- restrict the introduction of introduced species;
- enhance aesthetic values; and
- sustain natural evolution of the baylands.

In another paper, Herbold et al.[3] provide considerable discussion of key organism groups and important ecological parameters that may be considered as indicators of estuary health.

Kimmerer, W. 1995. Goals for Restoring a Healthy Estuary: Discussion Paper on Ecosystem Health. Paper prepared for Natural Heritage Institute Workshop: Goals for Restoring a Healthy Estuary. October 2, 1995. Natural Heritage Institute.

Herbold, B, A. Jassby, and P. Moyle. 1992. Status and trends report on aquatic resources in the San Francisco Estuary. San Francisco Estuary Project. University of California, Davis.

E-011673

The following is a summary list of possible indicators:

1. Various important types, amounts, and conditions of habitat;

2. Population abundance of important species (threatened and endangered species, key native fish, important sport fish, introduced species);

3. Toxic chemical levels in fish and shellfish tissues, water, and sediment;

4. Nutrient levels in water;

5. Dissolved oxygen level in water;

6. Water temperature;

7. Salinity;

8. Hydrologic characteristics (Delta inflow and outflow, diversion rates, reverse flows in Delta); and

9. Growth rates of individuals and populations of key species.

The CALFED Bay-Delta Program is pursuing an ecosystem health approach to finding a solution to the Bay-Delta system's ecosystem quality problems. It is believed that this approach will also substantially benefit the other resource areas by providing a more stable foundation to the Bay-Delta system. The plan is to follow an approach incorporating some of the concepts and information suggested above. An ecosystem strategy will be developed that crafts a vision for ecosystem health of the Bay-Delta system. A multistep process has been adopted with the first step being defining goals and objectives. The second step is to define ecological health indicators or performance measures for each of the objectives. Benchmarks defining state of ecosystem health will then be developed for each indicator. Each alternative solution scheme will be evaluated using ecosystem health indicators to measure performance in achieving ecosystem health.