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Research Needs for the Salton Sea[1]

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INTRODUCTION

I am pleased to be part of the UC-Mexico Salton Sea Workshop and have this opportunity for dialogue with others with scientific interests in the Salton Sea. My involvement with the Salton Sea began earlier in this decade when, as Director of the National Wildlife Health Center (NWHC), I was repeatedly notified of substantial bird die-offs at the Sea. Our Center was asked to investigate those mortalities and to provide assistance in resolving the cause for those events. Much has happened since then. The objectives for my presentation are first to identify the various actions that have taken place relative to developing science needs to address the issues of the Salton Sea and to place those action in context with other relevant events. I will then focus my attention on the ecology of disease affecting birds that utilize the Sea. I will conclude by providing information about the science activities about to be funded by the Salton Sea project, other needs being considered, and offer some philosophical comments for your consideration.

SCIENCE AND THE SALTON SEA

The Salton Sea has been an area for focus regarding remedial actions long before I became involved. Recognition of a problem involving increasing salinity and interest in corrective actions occurred during the mid-1960s (Bureau of Reclamation 1997). At that time,

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the Bureau of Reclamation (BOR) and the California State Department of Water Resources (DWR) jointly undertook feasibility studies relative to options available to manage salinity at the Sea. Study results and recommendations for an in-Sea evaporation pond were reported in 1969 and 1974 by those agencies. In 1986, The Resources Agency of California created the intergovernment agency Salton Sea Task Force to pursue practical solutions and associated funding mechanisms to address the problems of increasing water levels and salinity at the Sea. The State of California also hired a consultant to work on some aspects of these issues. In 1992, enactment of a Public Law by the U.S. Congress provided authority for Federal expenditures of up to $10 million for "investigation and development of a method or combination of methods" to address salinity problems at the Salton Sea. Matching expenditures by non-Federal entities of the State was required by this legislation. Formation of the Salton Sea Authority (Authority) in 1993 replaced the Salton Sea Task Force and provide local authority "to pursue remedies to problems facing the Salton Sea" (Bureau of Reclamation 1997).

The Joint Powers Agreement of 1993 that established the Salton Sea Authority as the local lead agency stipulated that the Authority would work to develop programs that would continue beneficial use of the Salton Sea. Beneficial use includes the primary purpose of the Sea as a repository for agricultural drainage, storm water, and wastewater flows; for protection of endangered species, fisheries, and migratory birds; and for recreation purposes (Bureau of Reclamation 1997). It is important to note that the focus of efforts to that point in time was essentially to address salinity and water elevation. A 1995 Authority workshop developed elimination criteria for screening a list of 54 alternatives proposed to address salinity and, in 1996, a public workshop was held to develop evaluation criteria for alternatives to be considered. The evaluation criteria were weighted in order of relative importance as determined by the workshop participants. Agricultural interests, wildlife, and elevation control received the highest values and were essentially equal with values of 33, 32, and 31, respectively.

These earlier, narrowly focused efforts were overtaken by continually increasing bird die-offs that attracted national, regional, and local media. These events and the associated media coverage drew my Center into this issue because of our role in addressing wildlife disease problems affecting species under stewardship of the U.S. Department of the Interior. The array, frequency, and magnitude of disease events in birds at the Salton Sea indicated this was an ecosystem under considerable stress. These concerns were conveyed by me to administrators within my agency along with a recommendation for a budget initiative to address ecosystem health at the Salton Sea.

The disastrous 1996 pelican die-off at the Sea accelerated visibility of the ecological problems of the Sea and helped to gain support for a workshop sponsored by and held at the NWHC during October 1996. The purpose of that workshop was to develop an issue paper that could be used to support a budget initiative to address ecosystem health at the Sea. This was a much broader perspective then the ongoing efforts that had begun in the mid-1960s. Representatives from six agencies participated in the October 22-23 workshop and developed a Salton Sea ecosystem initiative that contained recommendations for addressing the ongoing pelican die-off and long-term management needs as well. Immediate research needs identified focused on understanding the relations between avian botulism in pelicans and tilapia. The long-term goals focused on developing:

(1) a better understanding of the ecology of the Salton Sea;

(2) methodology for managing the Salton Sea ecosystem for maximum sustainability of economic and biological resources; and

(3) a long-term fiscal and personnel support base for addressing ecosystem health at the Salton Sea.

The ecology goal contained components involving the evaluation and synthesis of existing data, development of a conceptual model of the ecology of the Sea, and inventory and monitoring needs. The management goal contained components that considered socio-economic evaluations relative to biological outcomes, strategies for mitigation, and the development of an interagency coalition for information exchange and resolution of biological problems at the Sea. The fiscal goal sought Congressional support through agency initiatives, agency commitments to apply discretionary funds to resolving issues at the Sea, and collaborative initiatives by the coalition being developed. The issue paper resulting from the NWHC workshop was widely distributed in an attempt to gain support for funding a coordinated and collaborative science effort to address ecosystem health at the Sea.

Initial follow-up to the NWHC workshop occurred during August, 1997. Effort by the U.S. Fish and Wildlife Service resulted in more than 100 scientists, managers, and others convening in Palm Springs, California to develop an in-depth research needs assessment. That effort resulted in a document titled, "Saving the Salton Sea," which was released in October 1997. A total of 39 study proposals accompanied by a larger number of recommendations are contained within that document. Budgets were developed for 34 of those proposals, and totaled more than $36 million, or approximately $12 million per year for 3 years. During December 1997, Interior Secretary Bruce Babbitt expanded the role of the Federal government in Salton Sea issues after meeting with officials from other governmental agencies and the Torres Martinez Indian Tribe by forging a consensus for the initiation of two actions which are the foundation for the current Salton Sea project. These action are:

(1) Initiation of an open environmental review process under the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA) to identify and evaluate specific options for addressing the issues of the Salton Sea; and

(2) Establishment of a joint governmental coordinating mechanism to help coordinate and focus the efforts of the many governmental agencies who are involved in funding important research activities related to the Salton Sea.

The coordinating mechanism put in place was the formation of a Research Management Committee of high-level representatives of the four governments involved in the Salton Sea recovery effort. That Committee was directed to appoint a Science Subcommittee consisting of stakehold agency representatives to assist the Committee. I was appointed to head the Science Subcommittee. Since then, university representatives have been added to both the Research Management Committee and the Science Subcommittee. A key point is that the science effort provided for by this action is directly supportive of the NEPA/CEQA process. Therefore, the scientific exploration associated with this process is very pragmatic and highly focused on providing biological evaluations addressing potential environmental impacts, positive and negative, associated with project management alternatives being considered.

The action by Secretary Babbitt provided for the first major integration of science with management of the Salton Sea. It also expanded the scope for the project. Despite his action, a major detraction associated with the Salton Sea project has been continued statements by members of Congress, local officials, and members of the general public that the Salton Sea has been studied to death and additional studies are not needed. "NO MORE STUDIES" is the message continually transmitted. There have in fact been many investigations conducted at the Salton Sea. However, for the most part, these investigations have been narrowly focused and do not provide for the type of integrated database that allows the Sea to be evaluated in a manner that provides the information needed to adequately guide decisions within the current NEPA/CEQA process. A task for the Science Subcommittee is to identify the critical science needs that exist and to obtain the information needed.

Among past and current investigations are more than two decades of engineering evaluations of how to address salinity, a variety of water related monitoring studies and contaminant investigations carried out by the U.S. Geological Survey and others, university studies on various aspects of the Sea, disease investigations by government agencies and universities, and economic evaluations of the social values associated with various aspects of the Sea. In addition, several conceptual and issue focused models addressing various aspects of the Sea have been developed. The quality of these investigations varies widely, much of the data are historic rather than current, and there are few hypothesis testing studies among the work that has been completed. An opportunity now exists to bring these various interests together through the Salton Sea project and develop a coordinated science effort for addressing the environmental issues of the Salton Sea ecosystem.

AVIAN DISEASES

All diseases have three common factors: an agent that causes damage to the host in a manner that diminishes the health of the host; susceptible individuals and populations that are damaged by contact with the disease agents; and environmental factors that precipitate or facilitate interactions between the host and the agent in a manner that results in disease. The context for the term disease is an absence of health. Thus, disease is an outcome not a cause and can result from a broad spectrum of agents including those that are infectious and non-infectious, or are of a biological or physical nature. The same agents can act in different ways to cause impairment of the host. An example is salt. Physical salt loading destroys the integrity of feather structure and results in bird deaths due to several types of impairments; cataract formation is another impact from the physical contact with salt. Salt is also toxic for birds if

levels ingested are greater than those various species can tolerate. The levels of salt tolerance are negatively impacted by factors that impair salt regulation in birds. Organophosphate and carbamate pesticides are examples.

A wide variety of disease agents have been responsible for bird mortality at the Salton Sea. I will provide some brief comments about those of primary concern by focusing on the agent, the host, and the ecology of each of these diseases.

Avian Botulism

A. Status / Importance

1. Most significant, if not addressed, of the avian diseases occurring at the Sea relative to probable impacts on the variety of waterbirds that use the Sea.
2. Has occurred at the Sea since at least the 1930s.
3. Expanded geographical distribution worldwide since the 1960s-1970s.
4. Responsible for major pelican losses in 1996 that focused national attention on the Sea.

B. Agent

1. Clostridium botulinum type C.
2. Potent toxins produced during the growth stages of the bacteria are the cause of disease.
3. Different toxins, identified by the letters A to G are the causes of disease in different species and countries.

    a. Wild birds are almost exclusively victimized by type C.
    b. Type E occasionally occurs in fish-eating birds in the Great Lakes and at a few other locations.

C. Host

1. All species of birds that use the Sea are susceptible to type C toxin.
2. These same species are also susceptible to type E.

D. Ecology

1. Avian botulism is truly an environmental disease.

   a. Like tetanus, the organism exists in nature (soils, sediments) in an inactive spore form.
   b. The spores germinate and produce vegetative cells, which are the source of toxin, when exposed to appropriate environmental conditions.
   c. The ecology of avian botulism is further complicated by toxin production being mediated by bacteriophage infections of the bacteria which encode the bacterial cell to produce toxin.

2. Studies by scientists from the NWHC have clearly demonstrated that the interstitial water level is where toxin production takes place in wetlands.

3. These same studies have identified the water quality parameters that are important for toxin production and the range of values where this occurs.

   a. These relations are not linear.
   b. These relations are interactive rather than independent.

4. Water quality is only one component of the ecology of this disease.

   a. Cl. botulinum is a strict anaerobe, therefore, bacterial multiplication must take place in an environment that is without any oxygen.
   b. Cl. botulinum is also essentially a "meat lover" - it needs a source of protein for nourishment. This is usually an invertebrate or vertebrate carcass.

c. Avian botulism is basically a food poisoning requiring the ingestion of the toxin in food items.

5. Typically, avian botulism involves toxin production taking place in the gut of a decaying vertebrate carcass (usually a bird).

a. The spores are present in the intestines of animals that have fed in environments seeded with this bacteria.
b. Decomposition of the carcass during warmer months of the year provides appropriate environmental conditions for spore germination and multiplication of the bacteria.

6. When these carcasses become flyblown, the ensuing maggots consume the toxin along with the flesh and other carcass tissues.

a. Invertebrates are not susceptible to botulinum toxin due to having a different nervous system than vertebrates.
b. The maggots concentrate the toxin in their bodies.

7. Birds that consume as few as two toxic maggots are quickly killed and become additional incubators for toxin production, produce additional toxic maggots, and perpetuate the classic maggot cycle.

8. Fish-eating birds are rarely victimized by type C botulism because their food habits do not result in feeding on maggots.

9. Pelican mortality from this disease at the Salton Sea appears to be a different type of botulism cycle.

a. Preliminary investigations suggest that bacterial multiplication and toxin production are taking place in the intestines of live tilapia.
b. These investigations indicate that tilapia are highly susceptible to the toxin being produced within their intestinal tissues.

10. Pelicans appear to be become exposed to the toxin by feeding on sick tilapia which are dying from their intestinal infections of Cl. botulinum.

11. Therefore, there are two distinct types of avian botulism cycles occurring at the Sea.

    a. The pelican cycle can contribute to the maggot cycle, but the reverse does not occur.
    b. The pelican cycle is unique, as is the presence of two types of botulism cycles.

Avian Cholera

A. Status / Importance

1. Most significant infectious disease currently known to be occurring at the Sea relative to magnitude of losses this disease is capable of causing.
2. Most common cause of multiple bird death events reported for the Sea.
3. Like avian botulism, an increasing problem within North America since 1970.

B. Agent

1. Pasteurella multocida
2. Infectious and contagious bacterial disease that first occurred in wild birds in the United States in 1944.

C. Hosts

1. All species of birds that use the Sea are susceptible.
2. More than 100 species of wild birds documented to have died from infections (not at the Sea).

D. Ecology

1. Disease carriers are thought to be the source of outbreaks that occur.

2. Water quality has been shown to be an important factor regarding the survival time for bacteria shed into the environment from infected birds and from contamination associated with scavenging of carcasses.

3. Disease transmission occurs through direct contact with infected birds, ingestion of contaminated food or water, and bacterial laden aerosols of water droplets associated with the disturbance of water surfaces by the activities of birds.

4. Gulls and other scavenger species have extended incubation periods between exposure and clinical disease, thereby, serving to extend die-offs by also serving as new sources of contamination of the environment and as a vehicle for disease spread through their movement patterns.

Salmonellosis

A. Status / Importance

1. Occasional occurrence in nesting colonies at the deltas and surrounding areas.
2. Capable of infecting large-scale losses, especially in young birds.

B. Agent

1. Salmonella typhimurium primarily.
2. Infectious and contagious bacterial disease that is an emerging disease of wild birds.

C. Host

1. All species of birds that use the Sea are susceptible to infection.

a. Disease has essentially been confined to colonial waterbirds.
b. Most events have involved young of the year in rookeries.

2. Humans are susceptible.

D. Ecology

1. Carriers among the bird population are one potential source of infection.

a. Rodents are a common source for infection
b. Other species can also be sources for infection.

2. Ingestion of contaminated food and water is the usual route for infection by this bacteria.

3. Environmental conditions are a significant factor influencing the survival time for salmonella in the environment.

4. Feces from infected sources are the usual source of environmental contamination.

Newcastle Disease

A. Status / Importance

1. Cause of total loss of production in cormorant colonies on Mullet Island.
2. Disease eradicated from poultry in Canada and the United States by early 1970s.
3. Appearance at Salton Sea first time reported in wild birds west of the Rocky Mountains.

B. Agent

1. Newcastle Disease Virus
2. Highly pathogenic and virulent strain of the Newcastle Disease virus.

C. Host

1. Only cormorants have been found to be infected at the Sea.
2. White pelicans and gulls also found infected in Canadian outbreaks.
3. Chickens moderately susceptible to strain isolated.
4. Disease has been conferred to younger age classes and has been especially lethal in nestlings.
5. Humans can contract a mild respiratory and conjunctivitis from exposure to concentrated amounts of this virus.

D. Ecology

1. Only the ground nesting colony has been found to be infected.
2. Fecal contamination is an important means for virus transmission and results in different virus exposure potentials for ground nesting vs. tree nesting birds.
3. Recent occurrence of NDV in cormorants within Canada, the Midwestern United States, and now the Salton Sea is a matter of growing concern.

Algal Toxins

A. Status / Importance

1. Algal blooms are an increasing problem worldwide.
2. Algal blooms are increasing at the Sea but their importance as a source of toxins contributing to bird kills remains unknown.

B. Agent

1. Two primary types of algae of concern regarding toxins

   a. blue-green algae (cyanobacteria)

      (1) Hepatotoxins (i.e., caused by microcystins such as Microcystis aeroginosa)

      (2) Neurotoxins (i.e., such as anatoxins, saxitoxin, and neosaxitoxin.

   b. dinoflagellates.

C. Hosts

1. We suspect algal blooms are resulting in production of toxin responsible for the large grebe kill of 1992 and continue to be a source of grebe mortality.
2. Too little is known to assess potential impacts on other species.

D. Ecology

1. The clinical signs and pathological effects of algal toxins are poorly to not described for most birds.
2. Technology to diagnose algal toxicity remains largely inadequate.
3. Significance of finding algal toxins in the tissues of sick and dead animals is yet to be determined.

Other Toxins

A. Status / Impacts

1. There is no evidence of any significant problems from pesticides and other toxins regarding direct effects.

2. There have been a few small scale bird die-offs on on-farm locations following pesticide application - mortality associated with exposure to pesticide within the Sea has not been documented.

B. Agent

1. Lead poisoning from spent lead shot has been documented at the Sea (State Waterfowl Area).

2. Organophosphate and carbamates have caused minor on-farm losses and one moderate sized on-farm loss.

C. Host

All species present (birds) are susceptible.

D. Ecology

1. Sublethal effects may be occurring but have not been documented.
2. Interactions between salt gland function and modern pesticides should be evaluated.

FISH DISEASES

Massive fish kills occur at the Sea. It is thought that lack of oxygen in the water column in summer and cold water in winter is a primary factor. However, a wide range of pathogenic microorganisms and parasites have also been isolated from dead and dying birds.

SCIENCE AND THE SCIENCE SUBCOMMITTEE

The Salton Sea Science Subcommittee is a coordination and advisory body and does not carry out scientific activities beyond data synthesis and evaluations. No funding is vested in or controlled by the Subcommittee and neither its members, persons, or organizational units supervised by its members can profit from recommendations made by the Subcommittee. This arrangement is designed to maintain focus on the pragmatic task before us and to facilitate objectivity in our deliberations and actions. Further, we are by design a terminal Subcommittee whose task will have ended by January 2000 when recommendations for actions to be taken under the current Salton Sea project are transmitted to Congress by Interior Secretary Babbitt. However, science needs associated with the Salton Sea are long-term and will not have ended with the disbanding of the current Subcommittee. Therefore, in addition to addressing immediate science needs, we are also considering long-term science needs.

As previously noted, the immediate needs are directly associated with the NEPA/CEQA process. Our first Request for Proposals (RFP) was issued late in June. Selection of those we are recommending for funding was made last week. Studies to be conducted under these proposals will provide important reconnaissance level information about the Sea regarding:

1. Biological and physical limnology
2. Fish communities
3. Avian communities
4. Sediment contaminants
5. Microbial pathogens

Vegetative mapping is being provided through other means. All of these activities will be carried out in a coordinated manner and provide time sensitive information for evaluations within the NEPA/CEQA process. In addition, information synthesis is being undertaken to provide a better understanding of what is known and what yet needs to be determined. The University of Redlands serves as our database and source of technical assistance in this effort. The University is funded for this purpose by separate appropriations.

Additional RFPs issued by the Subcommittee will build upon these initial studies and enhance our basic understanding of the ecology of the Sea and provide a sound understanding of the ecological factors contributing to disease events in fish and birds. Modeling will be an important component of this effort and is something we are now turning our attention to along with basic ecological studies that will help to better define the functional relations between various components of the Salton Sea ecosystem. All of this information is fundamental for the development of baselines against which a monitoring program can be designed. The purpose for monitoring related to the current project is to evaluate whether or not management actions taken serve the project objectives in a positive manner, or if adjustments are needed.

The establishment of sound baselines and an ecologically sensitive monitoring program are fundamental building blocks for a long-term coordinated science effort that addresses problems of the Sea in addition to those being dealt with by the current focus on salinity and water level control. Both of these aspects along with in-depth scientific studies required to resolve those problems are the focus for Subcommittee development of a strategic science plan for achieving and sustaining an enhanced state of ecosystem health at the Salton Sea that serves all current project objectives. A series of subject specific expert workshops will be developed to help gather information to assist with our efforts. This strategic plan will be the culmination of our Subcommittee efforts and will likely also contain recommendations for some type of interagency body to coordinate science efforts at the Sea for the next decade.

CONCLUSION

The following closing comments are offered for your consideration. The current Salton Sea project is the first phase of what must be a multi-phased effort to improve the environmental quality of the Sea. Therefore, this project is a beginning not an endpoint. Science is the foundation of information needed to guide management actions throughout the entire effort. Therefore, the current scientific effort is also a beginning rather than an endpoint. There are many competing interest regarding the direction these scientific efforts should take, all of which have validity. The validity of those viewpoints exists regardless of whether one has a vested interest in a particular viewpoint or is a detached objective observer. How then do we select among those viewpoints?

At the risk of alienating many of you in attendance, I respond to that question by noting that science provides a foundation for management, but is not the determinant of management actions since scientific findings are only one factor in the equation leading to problem resolution. Management of the Salton Sea is an ecosystem management issue, and as noted by Robert Lackey:

> "Ecosystem management should maintain ecosystems in the appropriate condition to achieve desired social benefits; the desired social benefits are defined by society, not scientists."
>
> (Lackey 1998)

In this context, it is important to examine the divergent viewpoints of scientists noted above and objectively evaluate which of those viewpoints are responsive to the desires of society that must pay the bills and live with the outcomes, and which are simply responsive to our specific interests of scientific pursuit and personal values. When we favor the latter, rather than the former, as the scientific contributions we offer to the task at hand then we enhance a recent statement by Dr. Sanford Miller, a dean at the university of Texas Health Science Center who noted that "science is a destabilizing force in public policy" (Taubes 1998). In some aspects, it seems that science is promoting that image for the Salton Sea."

I was requested to address the topic of Research Needs for the Salton Sea for my presentation at this meeting. In doing so, I have attempted to illustrate how Science Subcommittee activities are associated with, and are relevant to, the desired social benefits defined by society for this project. In closing, I borrow an 1860 quotation of Thomas Huxley that I believe provides a good perspective for viewing the needs at the Salton Sea.

> "Science...warns me to be careful how I adopt a view which jumps with my preconceptions, and to require stronger evidence for such belief than for one to which I was previously hostile. My business is to teach my aspiration to conform themselves to fact, not to try and make facts harmonize with my aspirations."
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> (Huxley 1860)