California State Water Resources Control Board Hearing Regarding the Salton Sea

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Salton Sea Ecology

My name is Stuart Hurlbert, and I am a professor of Biology and Director of the Center for Inland Waters at San Diego State University, I have a doctoral degree in Ecology from Cornell University and have been at San Diego State University for 32 years. For 24 years I have taught a course on the ecology of the Salton Sea-Colorado delta region. For the past 12 years I have headed a research group that has been studying various facets of the ecology of the Salton Sea. During the last few years our group has received Salton Sea Authority/EPA contracts for investigation of the biological limnology, fisheries, and contaminants in the Salton Sea ecosystem. These studies have involved 38 scientists and graduate students at nine different institutions. I also have advised many other organizations on water-related ecological issues, and for eight years was a consultant to the Los Angeles Department of Water and Power on Mono Lake issues and research programs.

My task today is to briefly summarize the nature of the Salton Sea ecosystem, with some particular attention to how it may respond to increasing salinity levels and some commentary on the Draft EIR/EIS. This is a moderately large task as the Salton Sea is the largest lake in the state, our knowledge of its ecology has increased more than 10-fold in the past four years, and most of this new knowledge is not yet published, though about half of it will be published in the next few months in mainline scientific journals. The final report for our biological limnology investigations alone was 1100 pages long. This situation undoubtedly has been frustrating for those charged with preparing the EIR for the transfer project - most of the current information on the Sea had neither been peer-reviewed nor published when the EIR was being prepared.

My testimony is based on information that is summarized in particular documents or in manuscripts in preparation , as well as on personal observations made in the field at the Sea over many years. The principal documents used include, in addition to the water transfer EIR itself:

Detwiler, P. M., M. F. Coe and D. M. Dexter. 2002. The benthic invertebrates of the Salton Sea: distribution and seasonal dynamics. Hydrobiologia (in press).

Dexter, D.M. 1993. Salinity tolerance of the copepod *Apocyclops dengizicus* (Lepeschkin, 1900), a key food chain organism in the Salton Sea, California. Hydrobiologia 267:203-297.

Hurlbert, S.H. 1991. Salinity thresholds, lake size and history: A critique of the NAS and CORI reports on Mono Lake. Bull. South. California Acad. Sci. 90:41-57.

Riedel, R. and Costa-Pierce, B. 2001. Review of the fisheries of the Salton Sea, California, USA: past, present, future. Reviews in Fisheries Science 9:239-270.

SSERG. 2001. Reconnaissance of the biological limnology of the Salton Sea: final report. Salton Sea Ecosystem Research Group, Department of Biology and Center for Inland Waters, San Diego State

University, San Diego, California. 1100 pp. [this contains many manuscripts that are now either published or in press, as well as some preliminary reports].

The six critical defining features of the Sea ecosystem are these: **[Salton Sea satellite photo]**

1. It has a large surface area but is very shallow for its size.
2. It has no outflow.
3. It is fed primarily by agricultural and municipal wastewaters high in salts, nutrients, and certain contaminants.
4. It is located in a very hot climate.
5. It abounds in fish as a result of stocking of many marine species by Cal Fish and Game starting in 1929 and escape of some exotic fish species into the Sea in later years
6. It formed, in its most recent reincarnation, at the beginning of a century during which we destroyed or degraded most of the other wetlands and shallow lakes in the state.

To give you my broad view of the Sea, let me read the closing paragraph from an essay that I wrote in 1998. I was responding to an ill-informed op-ed piece that appeared in the LA Times. The piece stated that the Salton Sea was "dead" and an "environmental abscess" and that we should dry it up:

My response was:

> "For most of this century the Salton Basin has been the site of a tremendously positive symbiosis between agriculture, wildlife, human recreation, and, in the early days, commercial fisheries. Agricultural wastewaters have been and are the life blood of the system but also have given the lake more salts and more nutrients (nitrogen and phosphorus) than are ideal. Reducing salinity and nutrient levels, and dealing with their consequences in the meantime, will require solution of a number of technical, political and legal problems. For now let's focus on solving these problems and restoring the health of the symbiosis. If we dry up the lake we truly will create an "environmental abscess" in the region." -- S. Hurlbert 1998

Four years later the only point I would add is to say that drying up even one-fourth of it would also likely create an "environmental abscess."

But let's get a bit more technical. **[Salton Sea foodweb]**

Here's a simplified representation of the Salton Sea food web. It is simplified because the number of known species in the Sea is around 400 and growing - so we have to lump tens or hundreds of some species into a single box in some cases. And for most species, especially the microorganisms we don't know much about what they eat or who eats them.

We have various types of **algae** at the bottom of the food chain. Most are microscopic; some live suspended in the water column as plankton, others live on the bottom attached to sediments or hard substrates. Some are potentially toxic to invertebrates, fish or even birds, but the limited investigations to date have not implicated toxic algae in any of the fish kills or bird die-offs that have occurred at the Sea.

The abundance and productivity of the algae is what makes the lake so rich in fish and birdlife. It also makes the water very colorful - often yellow, brown, or reddish - and scares away some swimmers, though without good reason.

Photosynthesis by the abundant algae often leads to the surface waters being supersaturated with **oxygen** during the day. At night or deeper in the water column, however, oxygen consumption by organisms can deplete all oxygen present and lead to reducing conditions where hydrogen sulfide, a highly toxic gas, is generated. This is especially common during the warmer part of the year when the water column can remain stratified or unmixed for days or weeks at a time.

Feeding on the algae - and on each other - we have a large variety of unicellular **protozoans** and a smaller number of **invertebrates** - various types of small crustaceans, insects, annelid worms and nematodes. There are one copepod (*Apocyclops*), one amphipod (*Gammarus*), one annelid (*Neanthes*), and one barnacle (*Balanus*) that are especially abundant - each during its season - and serve as important food supplies for fish and certain birds.

The dominant **fish** in the Sea are four: tilapia, bairdiella, sargo, and corvina(Riedel and Costa-Pierce 2001). These feed on invertebrates and on each other, according to size and age and preferences. Tilapia is omnivorous and also can feed on larger phytoplankters, explaining why it is the most abundant fish in the Sea at present. All fish are good sport fish, though sargo is now extremely scarce. Corvina is highly predaceous and individuals up to 20 lb are still caught in the Sea.

The fish serve as food for a large number of fish-eating **birds** at the Sea, including the White and Brown pelicans, Double-crested cormorant, Western and Clark's grebes, Black skimmers, and various herons, egrets, and terns. Each species has its own preferred fish sizes and its own way of catching them. There is no inland water body in the Southwest that is more important habitat for fish-eating birds.

Then there are the **fisherman**, sharing this rich booty with the fish-eating birds. This is a unique and very attractive sportfishery, in the past the most popular inland sport fishery in the state. The abundance and size of the corvina and the fact that there is no limit on tilapia, which can weigh 2-3 lbs, have historically made it an outstanding recreational spot for fishermen especially from metropolitan areas of throughout southern California.

Here are just a few pictures of some of these creatures. [**dinoflagellates**]

These are **dinoflagellates**, a type of flagellated algae that are well-known throughout coastal areas of the world as the cause of red tides. These sometimes kill invertebrates and fish, and can also render shellfish toxic. At the Salton Sea, they are especially abundant in the spring when they can make the lake look like a bowl of black coffee.

These are just one of many types of algae present.

These are the most abundant members of the **zooplankton** in the Sea. [**metazooplankters**]

There are two principal types of **rotifers**. There is one copepod which is an omnivore, feeding on algae and protozoans, but which also is capable of feeding on soft-bodied invertebrates larger than itself, such as brine shrimp (Hammer and Hurlbert 1992).

There are **barnacles**. The adults attach to hard substrates around the margin of the Sea, but their microscopic larvae - such as shown here - are planktonic, especially abundant in winter and spring, and an important food supply for planktivorous fish.

Then there is the **pileworm**, Neanthes succinea, a segmented worm that can get up to 5 cm in length. It is the dominant macroinvertebrate living on and in Salton Sea sediments and a major prey item for fish.

Its larvae are microscopic and have a planktonic existence where they represent an important food source for zooplanktivorous fish.

Finally, one fish - a **corvina**. This individual is probably about 5 lbs, [**corvina**]
so you can imagine how happy fishermen get when they catch a 20-pounder.

Now let me say a little bit about some of the critical processes and phenomena in the Sea.

The single most important one is the ongoing gradual rise salinity that would be accelerated by reductions in inflows to the Sea. More on this later.

Almost as important is the process of **eutrophication**. That term is defined as the complex sequence of changes in aquatic ecosystems caused by an increase in the rate of supply of plant nutrients to water. The process has been going on for a long time at the Sea which is now considered a highly eutrophic body of water. It has been so loaded with nutrients for so long and the phytoplankton is so dense, that its production may actually be limited by self-shading rather than by insufficiency of any nutrient.

This figure shows how Salton Sea's trophic state compares [**lake trophic types**]
to that of other well-known lakes. Two key factors determining a lake's productivity or trophic state are the rate of **nutrient inputs** (shown for phosphorus on the Y-axis) and its **shallowness** (shown on X-axis). Shallowness makes it easy for nutrients that end up in the sediments to be recycled back into the water column by various processes.

Deep lakes with low nutrient loadings, like Lake Tahoe at the lower right, tend to have very clear water, low productivity and not much in the way of life in them. These are termed oligotrophic.

At the other extreme we have biological gold mines like the Salton Sea - shallow and with high nutrient loadings. These are called eutrophic. And an intermediate category, termed mesotrophic, can also be defined.

As you can see, the Salton Sea has headed further into the 'eutrophic corner' during the last three decades. Phosphorus loading has more than doubled, apparently as a result of population growth in Mexicali, most municipal wastewaters of which flow down the New River and into the Salton Sea.

Note also that if lake level drops and mean depth decreases, the Salton Sea would be pushed further into the 'eutrophic corner', especially if wastewaters from Mexicali continue to increase.

The upside of eutrophic lakes is that they have rich food supplies. The downside is that they are subject to becoming partially or completely anoxic for longer or shorter periods. And such anoxia can be lethal to microorganisms, invertebrates, and fish, especially if accompanied by the presence of significant amounts of sulfide. This is what goes on at the Salton Sea now.

Let me illustrate this by referring to the temperature and oxygen regimes [**1997 Temp**]
the Sea experienced in 1997. Look at the temperature profiles first. In January and February the water column was little stratified, and water temperatures were below 15 C. Over the next 8-9 months the whole lake gradually warmed, but with the bottom waters lagging behind the surface waters. On most dates in spring and summer, the bottom waters were several degrees cooler than the upper waters. This indicated that the lake was in a stratified condition. A vertical density gradient existed, and the bottom and surface waters had not mixed for some period of time.

Now consider the oxygen profiles for the same period. This is the important part of the story. Notice that the profiles march in the opposite direction, because warm water can hold less oxygen than can cold water. So as spring progresses, the profiles shift to the left. In early spring we found reasonable levels of oxygen at all depths. But starting in May (the dark green line) the bottom waters were usually anoxic or nearly so. [**1997 Oxygen**]

Because these bottom waters continued warming up through the summer, it was evident that at intervals of several days to a few weeks, conditions were windy enough to completely mix the water column. This was the mechanism that delivered heat to the bottom waters.

These mixing events occasionally, especially in late summer or early fall, caused the entire water column to briefly become anoxic or nearly so, with high levels of hydrogen sulfide even in surface waters. Massive mortality of phytoplankton, zooplankton, and fish occurred at those times.

The first and milder such events in the spring probably were responsible for eliminating the pileworm from all but the shallowest (<4m deep) portions of the lake bottom. They also were likely the stimulus for virtually all fish populations to move to nearshore waters for the duration of the warmer half of the year.

As you can see, the present-day Salton Sea ecosystem is productive, dynamic, and complex. We are here today because the proposed transfer of water from IID to San Diego will have dramatic impacts on that ecosystem. I will discuss those in subsequent testimony for Defenders of Wildlife.