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INVESTIGATIONS OF ECOSYSTEMS IMPACTS FROM GEOTHERMAL DEVELOPMENT IN IMPERIAL, VALLEY, CALIFORNIA

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ABSTRACT

A summary of three years of field ecological investigation in Imperial Valley Environmental Program is presented. The potential terrestrial habitat impacts of geothermal development are discussed for shorebirds and waterfowl habitat, the endangered clapper rail, powerline corridors, noise effects, animal trace element burdens, and the desert community. Aquatic habitats are discussed in terms of Salton Sea salinity, effects of geothermal brine discharges to the Salton Sea, trace element baselines, and potential toxicity of brine spills in freshwater. Studies of impacts on agriculture involved brine movement in soil, release of trace metals, trace element baselines in soil and plants, water requirements of crops, and H_2S effects on crop production in the presence of CO_2 and ozone.

INTRODUCTION

A three-year project was begun in January 1976 to determine the potential impacts of geothermal development on Imperial Valley ecosystems. The four Imperial Valley KGRAs of concern were the Salton Sea, Brawley, Heber, and East Mesa KGRAs which encompassed land-use in wildlife preserves, recreational fisheries, agriculture, and desert. Our investigations were based on integrated field studies of specific development sites, shoreline habitats, aquatic habitats, desert habitats, water resources, agriculture, and air pollution effects. The scope of these investigations included baseline studies of the Imperial Valley Environmental Project (IVEP) and sufficient effects studies for a pre-development assessment of long-term impacts. The results reported here are chiefly those obtained through the IVEP and its subcontracts. Details of each specific study may be found in the numerous reports which this presentation summarizes.

TERRESTRIAL HABITAT IMPACTS

The hot water resource of Imperial Valley varies considerably among the KGRAs in its properties of dissolved solids and heat energy. As a result the various strategies of development led us to consider accidental brine spills on ecosystems and habitat disturbance as key issues.

The Salton Sea KGRA encloses wildlife refuges for migratory waterfowl (3% of the Pacific Flyway) and for important shorebirds. Approximately 15% of the total population of Yuma Clapper Rails nest in this KGRA. Wildlife biologists have pointed out that the worst problem confronting all shoreline wildlife habitats in general is the encoachment of the Salton Sea causing loss of marsh habitat, mud flats, roost trees, and food production.1 On top of this, habitat destruction is likely during construction and operation in the immediate area of the geothermal facility and well pads.

In the critical habitat of the Yuma Clapper Rail, however, development must be excluded except by slant drilling or similar avoidance methods. This shy, endangered bird was an enigma until under our program Bennett and Ohmart determined its feeding and nesting requirements.[2] Rails used fresh water areas containing mature stands of cattail and bubrush and were highly influenced by fluctuating water levels. Rails migrated to Imperial Valley in mid-March and remained until October, coinciding with the appearance of their main food which was crayfish.

Powerline corridors in the Salton Sea KGRA may conflict with flight patterns of birds. Within 1.6 km (1 mile) of the Salton Sea shore powerlines should be eliminated from consideration. Leitner found that in this range the traffic of birds between roosting and feeding areas overlapped many altitude zones, depending on species and weather conditions.[3] Furthermore, cattle egrets tended to follow the river courses which suggests that special powerline construction should be considered at river crossings.

Noise effects will not likely be a continuing problem in Imperial Valley. Measurements of sound pressure levels (SPL) by Leitner determined that most geothermal drilling operations in Imperial Valley will not exceed 80 dBA at a distance of 15 m, although exceptions might occur in instances where no data were obtained, such as during well cleanouts. Noise levels during normal operations are now well-known, so that in general, the SPL of all operation should drop off to 54 dBA at 300 m. Such levels are expected to produce Little change in background noise Levels.

Studies of trace element burdens in liver and kidney tissue of birds by one of us (Koranda) provided a baseline showing impacts from pesticides, fertilizer, and the local biogeochemistry. Birds were classed as waterfowl (pintail duck, ruddy duck, shoveler duck, green wing teal, snow goose and Canada goose), landbirds (sparrow hawks, roadrunner, and doves) and gulls (ring billed gull). Waterfowl acquired a higher concentration of Ni, Se, As, and Pb over the winter. Each particular species obtained an elemental signature of its own depending upon feeding habits. But as a group, waterfowl acquired elevated Ni and As from agricultural residues in the drainage water to the Salton Sea, elevated Se from biogeochemical origins, and elevated Pb from ingesting spent shot (Table 1).

found that there were almost no abnormal dorsal fin ray counts in corvina and gulf croaker but spine counts were lower in sargo.[6] Stomach contents and spawning indices were also determined to help explain population dynamics. It was found that all game fish were similar in toxic trace element content of muscle tissue (Table 2, Part A). Pooled tissue samples for mollies and pileworms further down the food chain had higher trace element levels than game fish, however. One of us (Ireland) conducted quarterly baselines of the pileworm and determined that, after keeping the pileworms alive for 96 hours to expel wastes, the tissue levels reflect the trace element content of the sediment (Table 2).

TABLE 1. TRACE ELEMENTS IN WATERFOWL LIVER AND KANGAROO RAT LIVER ($\mu g\ g^{-1}$).

Element:	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Pb
Waterfowl (118)*	1.4	96	136	1.4	19	12	6	1.1	0.8-133
Kangaroo rat (22)*	6.3	33	110	-				0.9	

*Numbers of animals in parentheses; kangaroo rats for 1977 samples at East Mesa.[4]

Studies of desert ecosystems in the East Mesa KGRA concentrated on determining community relations and, in anticipation of accidental brine spills, determining the heterogeneity of chemical elements among the sampled populations.[4] Because of slow recovery in the desert, construction and operation of a geothermal facility would create a severe, local, habitat disturbance, which would result in an ecosystem write-off within a limited site-specific area. Mineral composition of soil, herbs, and shrubs and for tissue from two species of kangaroo rat (Dipodomys deserti and D. merriami) from several plots were determined. Variation in several elements were detected between plots and from year to year. Grouping the 1977 data for both species of kangaroo rats, for example, showed elevated nickel and copper (Table 1).

AQUATIC IMPACTS

The Salton Sea has provided an important sportfishery for many years and will continue to do so for some time because the discharge of freshwater into the Salton Sea will exceed the evaporation rate and spawning will succeed in low salinity patches along the shore. The Salton Sea food chain is unusual in that no plankton eating fish exist, the game fish highly depend upon a benthic pileworm (Neanthes succinea), and a recent invasion has incurred by Tilapia zillii, a fish of increasing importance. Under our program, Oglesby showed that the pileworm reproduction will succeed in salinities at least 25% higher than present and perhaps higher, and that adults will survive nearly twice the present salinty for a few days.' An accidental brine discharge to the Salton Sea could have, in addition to mortality caused by an acute salinity shock, a longer-term effect due to the contamination by heavy metals. A baseline study of meristic stress indices and trace element burdens in fish was conducted. We

Mollies (Poecilia latipinna) had a cumulative mortality of 40% when exposed to 5% geothermal brine in Salton Sea water for two weeks, following acclimation to Salton Sea water (22,000 ppm TDS) for two weeks.[6] In Ireland's studies, pileworms withstood a 5% geothermal brine added to Salton Sea water for 30 hours (LT_{50}), 1% for 13 days, and 0.5% for 22 days.

The freshwater resources of the Imperial Valley are the New and Alamo Rivers, which collect agricultural drain water and discharge it into the Salton Sea, and the numerous canals carrying Colorado River water. Calculations showed that intrusion of a geothermal brine into irrigation water causes changes in the chemical speciation of trace elements such that biologically, Cd and Hg are greatly increased in availability, Ni remains available, As and B become largely unavailable, while Cu, Pb and Zn become somewhat unavailable but in fractions dependent upon the initial dilution.[7] (This kind of result also occurs for brine intrusions into Salton Sea water). Thus the effects of brine spills are difficult to predict without specifics about the rate and duration of spill. Nevertheless we have conducted bioassays of the economically important fish, Tilapia, which is used to control weed growth in drainage ditches. Ireland has developed a relative toxicity index and found that other than after the initial salinity shock from major ions (Cl, Na), the most toxic ions of Imperial Valley geothermal brine were, in order of toxicity; NH_4, B, Li, Mn, and Zn with Pb and Cu practically insignificant. We also examined the economically important mosquitofish, Gambusia, and found it to be resistant to brine spills.[8]

IMPACTS ON AGRICULTURE

Agriculture in Imperial Valley produces more than $500 million annually and is thus of major

TABLE 2. TRACE ELEMENT BASELINES OF THE SALTON SEA.

Element:	C"	Zn	Br	Sr	Pb	As	Investigator
Part A. Concentrations in Tissue ($\mu g\ g^{-1}$)							
Corvina (muscle)	0.80	16.9	3.27	2.15	0.33	-	Tullis[6]
Croaker (muscle)	0.67	17.0	3.48	6.05	0.99	-	Tullis[6]
Sargo (muscle)	0.99	17.0	4.78	6.82	1.04	-	Tullis[6]
Mollies (pooled tissue)	9.10	95.2	5.26	381.0	2.16	-	Tullis[6]
Pileworms (pooled, 96h)	10.5	116.0	13.1	39.0	-	16.7	Ireland
Part B. Concentrations in Water and Sediment ($\mu g\ g^{-1}$)							
Salton Sea water	0.008	0.060	12.0	11.0	-	0.0	Ireland
Salton Sea sediment		93.3	17.0	307.0	-	9.6	Ireland
Salton Sea sediment		202.0	90.6	411.0	-	14.7	Koranda

concern. We investigated the present status of agriculture via trace element baselines of soils and crops in an extensive network in Imperial Valley. Trace element levels of soils and crops reflect the intensive use of fertilizers and pesticides and the biogeochemical background in Imperial Valley.

An intensive network around the San Diego Gas and Electric pilot plant at Niland showed that trace elements in soil are rather homogeneously distributed both with depth in the soil and horizontally across a given field. However, there was a systematic large-scale biogeochemical gradient in several trace elements from the Niland site for 48 km (30 mi) southward toward the Mexican border, to the extent that As, for example, decreased from 9.5 to 3.0 $\mu g\ g^{-1}$.

TABLE 3. TRACE ELEMENT BASELINES IN SOILS AND CROPS ($\mu g\ g^{-1}$)

Element	Br	Ni	Rb	Sr	Zn
Surface soil	-	46.5	87.7	156.0	87.6
Sugar beet leaves	23.6	3.24	12.8	54.4	30.7
Lettuce leaves	39.5	-	16.4	121.0	53.3

Selected trace element baselines for soils and plants sampled in extensive network covering the whole Imperial Valley shown in Table 3.

Our preliminary estimates are that a geothermal brine spill on most Imperial Valley soils would effectively result in loss of that land to agricultural use. It would take 3-10 years to reclaim the soil by leaching the brine unless the spill occurs immediately above a tile drain, which case would still require l-3 years to leach.[9] Furthermore, some undesirable metals would become mobile. Our soil column leaching studies (Tompkins) found that the brine caused release of large amounts of Cd, Pb, B, Cu, and Zn which were not originally in the brine itself. Tompkins found that the geothermal brine applied to the soils is more toxic to sugar beets than a salt solution of the same concentration, and the geothermal brine caused significant increases of Se, Br, and other trace elements to appear in the leaves. Hence reclamation of a brine spill is difficult, and the consequences greater than merely a salinity effect.

Water resource allocation is potentially another issue of importance to agriculture. There is no excess water to be shared with geothermal development. Pruitt found in our study that economics now favors water-consumptive crops.[10] In irrigation terms of acre-feet of water per acre-year, the major crops require: alfalfa 6.75, sugar beets 3.80, cotton 3.50, wheat and oats 2.10, barley 1.80, and sorghum 1.70. Alfalfa occupies 40% of the total crop area but requires more than 60% of the available water.

Potential air pollution effects due to geothermal development were studied extensively. H_2S was of concern as a pollutant, but it exists in a mixture with CO2 in the non-condensable gas emissions and ozone (03) is also present in Imperial Valley at certain times. One of us (Kercher) developed a model by which photosynthesis and growth effects were investigated based on experimental, bioassay dose-response data with mixtures of gases.[11] The model reconciled that the threshold concentration for growth injury (dry matter production) in crops, such as measured by Thompson and Kats[12,13] is an order of magnitude lower than for photosynthesis as measured by Shinn *et al*[14] and by Coyne and Bingham.[15] At low concentrations H_2S stimulates growth of crops but at 0.3 ppm H_2S a significant reduction of growth occurs (Table 4), when the conditions are the worst possible -- continuous exposure to H_2S with plants stomata1 pores well opened. Furthermore, when CO2 is present the effects of H_2S are ameliorated (Table 4). The threshold for injury to Imperial Valley crops under these conditions is about a factor of ten higher than the California Air Quality Standard for H_2S. The presence of ozone increases H_2S toxicity to photosynthesis of snap beans and probably to other crops (Table 5),[15] but this was not detectable in the yield of the same crop.[16]

It was also found however that 0.3 ppm H_2S + 50 ppm CO2 increases the mortality and decreases life span of honeybees, and although this is of concern primarily to the seed production crops, such as alfalfa, its effect is minor and amelioration is possible by adding extra bee colonies.[17]

TABLE 4. REDUCTION OF H_2S INJURY TO LEAVES BY ADDED CO2
% Dry matter production

Treatment	Sugar beet	Lettuce	Alfalfa	Cotton
Control	100	100	100	100
.3 ppm H_2S	110	82	82	90
.3 ppm H_2S + 50 ppm CO_2	134	85	104	108

TABLE 5. OZONE INCREASES H_2S TOXICITY TO SNAP BEANS

H_2S Alone	Max Photosynthesis	H_2S + Ozone	Max Photosynthesis
(ppm)	(mg $CO_2dm^{-2}h^{-1}$)	(ppm)	(mg $CO_2dm^{-2}h^{-1}$)
0	29	0 + .07	24
.74	32	.74 + .07	27
3.3	19	3.3 + .07	15
5.0	16	5.0 + .07	15

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