Boron Contamination of Waterfowl at the Salton Sea and Implications for Avian Impacts

Introduction

The Reconnaissance Investigation (Setmire *et al.* 1990) conducted at the Salton Sea under the Department of the Interior s National Irrigation Water Quality Program (NIWQP) identified boron as a contaminant of concern for wildlife. In that study waterfowl liver concentrations of boron ranged up to 150 g/g dry weight (DW). The Detailed Study, conducted as a follow-up to the previous study, found that ruddy duck liver concentrations of boron increased during the course of their winter stay at the Salton Sea (Setmire *et al.* 1993).

Laboratory studies with mallards indicate that reproductive impacts can occur at dietary concentrations of boron that have been found in waterfowl food items in the San Joaquin Valley (Smith and Anders 1989). Black rails (*Laterallus jamaicensis*) nesting along the Salton Sea were experiencing a rapid decline, and there were concerns that the Yuma clapper rail (*Rallus longirostris yumanensis*), which is a federally listed endangered species, may be exposed to whatever conditions were causing the decline in black rails. This, along with the concentrations of boron found in the two NIWQP studies, prompted a more focused evaluation of the potential for toxicity or reproductive impacts from boron through studies of waterfowl at the Salton Sea.

Methods

Sediments and vegetation samples were collected from 3 sites to evaluate boron accumulation in water of different types (Figure 1). The Alamo River is a mixture of water from several sources including Colorado River water from irrigation canals, subsurface irrigation drainage, surface run-off from agriculture, and other surface run-off. The Bruchard drains carries predominantly subsurface drainage and surface run-off from agriculture. The Hazard 6 pond receives Colorado River water purchased from the irrigation district and delivered through the agricultural delivery system. The collections spanned the majority of the waterfowl winter stay at the Salton Sea.

Three sediment samples were collected from each of the three sites. The samples were collected in October and December of 1991 and February of 1992. The sediment samples were collected using a petit ponar dredge and placed in chemically clean jars. Sediments touching the surfaces of the ponar were avoided, and the ponar was thoroughly rinsed in site water before it was deployed at each site. The samples were placed on ice in the field until they could be placed in the freezer at the Salton Sea National Wildlife Refuge. The samples were transported to the Carlsbad Fish and Wildlife Office for shipment to the analytical laboratory.

The vegetation samples were collected from the same sites and at the same times as the sediments. Alkali bulrush (*Scirpus maritimus*) leaves were collected by hand using scissors. The samples were placed in chemically clean jars and handled similarly to the sediment samples.

Aquatic invertebrates collected included water boatmen (Corixidae) and pileworms (*Neanthes succinea*). Water boatmen were collected with light traps and hand held nets. Pileworms were collected by sieving through sediments and pelagic stages were caught with hand held nets. Pileworms and water boatmen were collected on a monthly and bimonthly basis, respectively, at established stations around the Salton Sea (Figure 1). Samples collected represented composited samples of >10 g.

Waterfowl were collected at several locations around the south end of the Salton Sea where they are known to forage. Birds were collected by Carlsbad Fish and Wildlife Office and Salton Sea National Wildlife Refuge staff using steel shot in February, July, September, October, and December of 1991 and February, March, and April of 1992. The carcasses were transported to the Salton Sea National Wildlife Refuge where the livers were removed, placed in chemically clean jars, and frozen. Snow geese (*Chen caerulescens*), northern shovelers (*Anas clypeata*), northern pintails (*Anas acuta*), and ruddy ducks (*Oxyura jamaicensis*) were collected. The liver samples were also transported to the Carlsbad Fish and Wildlife Office for shipment to the analytical laboratory.

Boron analyses were conducted by the Environmental Trace Substances Research Center at the University of Missouri, Rolla. Inductively coupled plasma spectroscopy was used following a HNO_3-$HClO_4$ digestion.

Results

The sediment boron concentrations are summarized by site in Table 1. The highest mean boron concentration in sediments was found in the Hazard 6 pond (at 7.5 g/g DW), with inadequate detections from the Bruchard drain for calculation of a mean. This is the opposite of what was anticipated based on the fact that the irrigation process results in evaporative concentration of boron from the Colorado River into the drain water (Setmire *et al.* 1993) and that the Bruchard drain carries drain water versus the Hazard 6 pond which is filled with Colorado River water. However, the Hazard 6 pond is a very low-flow system that might enhance evaporative concentration within its confines resulting in higher boron concentrations in the sediment than in the drain or river.

When evaluating the data based on the time of collection, a pattern was apparent. At all three sites the highest concentrations were found in October and the lowest occurred in December. February concentrations were intermediate. The cause of this is not clear, but may result from differences in evaporation rates from October through February. Based on temperature and day length, evaporation rates would be expected to be highest in October and lowest in December.

Bulrush concentrations are also summarized by site in Table 1. In this case, the Alamo River site had the highest mean concentration (17 g/g DW) with the Bruchard drain again the lowest (9.8 g/g DW). This is likely related to a combined exposure from sediment- and water-borne boron at each site. Water concentrations of boron were not measured. Although the pattern of concentrations by site differed from that for sediments, the pattern relative to time of collection was the same as that in the sediments with the highest concentrations in October and the lowest in December.

Invertebrate concentrations are summarized in Table 2. Invertebrate concentrations were similar between the two invertebrate groups. Water boatmen had the higher maximum concentration at 41 g/g DW, but the mean concentration for this group was 12 g/g DW. The mean concentration for pileworms was higher at 21 g/g DW, but the maximum for this group was 26 g/g DW. Water boatmen were collected from the Bruchard drain at the same times as the sediments and vegetation, and the concentrations showed a similar temporal pattern. The highest concentration was in October (20 g/g DW) and the lowest was in December (<8.9 g/g DW). One water boatmen sample was collected from the Alamo River, and its concentration (13 g/g DW) was within the range seen in vegetation at that site.

Waterfowl liver concentrations are summarized by species in Table 3. In all species detectable results occurred in less than 50 percent of the analyses so means were not calculated. Seasonal patterns were seen in the data for northern shovelers, northern pintails, and ruddy ducks. This is summarized in Table 4. All three species had largely non-detectable concentrations in the December 1991 collections. For northern pintails and ruddy ducks the highest mean concentrations were found in the September 1991 collections. Northern shovelers also had measurable concentrations in September 1991, but the highest mean boron concentration for this species was found in the March 1992 collections. Intermediate means for northern shovelers and ruddy ducks occurred in February 1991.

<u>Discussion</u>

The results indicate that overall boron concentrations at the Salton Sea are relatively low. The highest sediment concentration measured was 8.5 g/g DW. This is well within the range of naturally occurring boron in soils (Sprague 1972, as cited in Smith and Anders 1989), and similar to what were considered reference sediment concentration levels in Powell *et al.* (1997). It is also well below the mean for boron in soils of the western United States provided by Setmire *et al.* (1990). Setmire *et al.* (1993) demonstrated that the source of boron was Colorado River water and concentrations in the water were the result of evaporative concentration. Based on the limited sampling conducted here, this process has not resulted in greatly elevated concentrations of boron in the sediments of these areas during the course of this study.

The highest concentration in vegetation found in this study was 30 g/g DW. This is well below the highest concentration measured by Setmire *et al.* (1990), but the species were not the same.

However, bulrush concentrations in that study had boron concentrations as high as 130 g/g DW, with a mean of 68.6 g/g DW, much higher than those measured here. Similar high concentrations were seen by Setmire *et al.* (1993) in cattails in San Felipe and Salt Creeks, but the source and the water concentrations of boron in these creeks is not known. Powell *et al.* (1997) used vegetation as a reference that had 12-41 g/g DW. The concentrations measured here were 6-30 g/g DW. This suggests that these boron levels should not be considered to be elevated.

From the perspective of vegetation as a food item for waterfowl, the results of Smith and Anders (1989) suggest there may be cause for concern. They found that dietary concentrations as low as 30 g/g wet weight (WW, dietary moisture of 10%) resulted in reductions of duckling weight gain. This is similar to the high concentrations found here. However, Stanley *et al.* (1996) found a reduction in duckling growth only at the highest concentration they tested (900 g/g). The overall mean for the vegetation samples collected was 13 g/g DW. Sampling a broader array of waterfowl food items over a wider area at the Salton Sea would be necessary to determine what the overall exposures are for waterfowl. Boron is eliminated quickly (Pendleton *et al.* 1995), and it would therefore pose little reproductive risk to species that only winter at the Salton Sea. Most waterfowl do not breed at the Salton Sea. Snow geese and northern shovelers only winter there. Ruddy ducks are common year round, but they do not breed at the Salton Sea in large numbers. Northern pintails breed more commonly in the area, but the core of this species breeding occurs in the prairie potholes of the northern plains. The greatest risk from boron appears to occur in species breeding in areas that also have selenium contamination and limited protein in the diet (Hoffman *et al.* 1991). Although selenium is elevated in the Salton Sea ecosystem, we have no data to indicate that dietary protein is limiting. All of this suggests that the bird species consuming this vegetation are not likely to be impacted by boron at the Salton Sea.

The means for aquatic invertebrates were 12 g/g DW (1.8 g/g WW) for water boatmen and 21 g/g DW (3.9 g/g WW) for pileworms. The concentrations measured in pileworms were well below the concentrations found by Setmire *et al.* (1993). The mean found in that study was 70 g/g DW with a range of 22-160 g/g DW. Eisler (1990) identified a range of 6-47 g/g DW boron as background for aquatic insects, and a dietary level of <13 g/g WW as being below effects thresholds for waterfowl. Our results fall within this background range and below this dietary threshold as well as the lowest adverse effect level described by Smith and Anders (1989) of 30 g/g WW. It is not clear why this study found consistently lower concentrations of boron than Setmire *et al.* (1993). It may be related to differences in the overall volumes of irrigation being applied during the course of the two studies. The results described here indicate a low risk of impacts to birds from boron in the Salton Sea system.

The results of the liver analyses for the waterfowl species collected also suggest that impacts from boron are unlikely. Of the analyses conducted on liver samples, greater than 50 percent did not find detectable boron concentrations (detection limit of 2 g/g DW). The highest concentration found was for a northern shoveler at 9 g/g DW. Similar concentrations were found by Hoffman *et al.* (1991) for birds not supplemented at all or supplemented only with selenium. Smith and Anders (1989) had similar concentrations in birds on 30 g/g WW in the diet, higher supplementation rates resulted in liver concentrations that were higher than any of the concentrations found here. The concentrations measured here (considering the frequency of non-detects) were also lower than those measured previously at the Salton Sea (Setmire *et al.* 1990, 1993), and no increase over the course of the winter was found as was found by Setmire *et al.* (1993). Additional monitoring would be needed to determine if this is a consistent trend.

Overall, the risk presented by boron to waterfowl wintering at the Salton Sea appears to be low. Because breeding is minimal there and boron is eliminated from the system rapidly, efforts to control waterfowl exposure to boron do not appear to be necessary. In addition, based on the dietary concentrations measured in vegetation and invertebrate samples, boron does not appear to pose a major risk for resident or breeding bird species at the Salton Sea at this time. However, analysis of eggs for their boron concentrations would be needed to confirm this. Eisler (1990) identified a range of 3.2-8.0 g/g fresh weight in the egg as being capable of causing a wide range of developmental abnormalities. Previous studies conducted by this office did not find concentrations at this level in the limited range of species sampled (Bennett 1998 and Roberts 1996).

Current management efforts should focus on controlling exposure to selenium and DDT for breeding species at the Salton Sea based on results of previous studies (Bennett 1998). However, there are pending actions in the Imperial Valley that could greatly alter the existing conditions relative to boron and other system contaminants. The large scale water conservation currently being planned may increase boron concentrations throughout the system and at all levels of the food chain. This should be monitored and addressed as appropriate through future management actions in the Salton Sea system. In the broader perspective of ecosystem health, additional studies of pathogens and disease relative to nutrients, salinity, dissolved oxygen, and other water quality parameters are also indicated for the protection of fish and wildlife resources at the Salton Sea.

Table 1. Boron concentrations (geometric mean[a] and range[b] in g/g dry weight) in sediments and vegetation collected from the vicinity of the Salton Sea.

Site	Sediment concentration	Vegetation concentration
Alamo River	= 3.5, range = <2 - 7.4	= 17, range = 12 - 30
Bruchard drain	= -----, range = <2 - 4	= 9.8, range = 6 - 13
Hazard 6 pond	= 7.5, range = 6.7 - 8.5	= 14, range = 7.1 - 25

[a] Geometric means were calculated for groups with <50% non-detect results.

[b] Three samples of each matrix were collected from each of the three sites.

Table 2. Boron geometric mean and range concentrations (in g/g dry weight) in invertebrates collected from the vicinity of the Salton Sea.

Species	Geometric Mean	Range
Water boatmen (Corixidae)	12	<8.9 - 40
Pileworms (*Neanthes succinea*)	21	16 - 26

Table 3. Boron concentrations (ranges only[a] in g/g dry weight) for waterfowl livers collected at the Salton Sea.

Species	Sample size	Concentration range
Snow goose	6	<2 - 4
Northern shoveler	34	<2 - 9
Northern pintail	30	<2 - 6

Ruddy duck	40	<2 - 4

a There were >50% non-detect results for all species.

Table 4. Boron liver concentrations in g/g dry weight by month of collection for selected Salton Sea waterfowl.

Species	Sampling period	Sample number	Geometric mean[a]	Range
Northern Shoveler	2/91	4	2.7	<2 - 9
	9/91	10	1.9	<2 - 5
	12/91	10		<2
	3/92	10	2.9	<2 - 6.4
Northern pintail	9/91	10	3.3	2 - 6
	12/91	10		<2 - 2
	2/92	10		<2 - 4
Ruddy duck	2/91	5	1.9	<2 - 4
	7/91	5		<2
	9/91	10	2.6	2 - 4
	12/91	10		<2 - 3
	3-4/92	10		<2 - 3

[a] Geometric means were calculated for groups with <50% non-detect results

References Cited

Bennett, J. 1998. Biological Effects of Selenium and other Contaminants Associated with Irrigation Drainage in the Salton Sea Area, California, 1992-94. Information Report No. 4, Department of the Interior National Irrigation Water Quality Program, Washington, D.C. 35pp.

Hoffman, D.J., C.J. Sanderson, L.J. LeCaptain, E. Cromartie, and G.W. Pendleton. 1991. Interactive effects of boron, selenium, and dietary protein on survival, growth, and physiology in mallard ducklings. Arch. Environ. Contam. Toxicol. 20:288-294.

Pendleton, G.W., M.R. Whitworth, and G.H. Olsen. 1995. Accumulation and loss of arsenic and boron, alone and in combination, in mallard ducks. Environ. Toxicol. Chem. 14(8):1357-1364.

Powell, R.L., R.A. Kimberle, G.T. Coyle, and G.R. Best. 1997. Ecological risk assessment of a wetland exposed to boron. Environ. Toxicol. Chem. 16(11):2409-2414.

Roberts, C.A. 1996. Trace Element and Organochlorine Contamination in Prey and Habitat of the Yuma Clapper Rail in the Imperial Valley, California. Report submitted to the U.S. Fish and Wildlife Service Regional Office, Portland, Oregon. 20 pp.

Setmire, J.G., J.C. Wolfe, and R.K. Stroud. 1990. Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Salton Sea area, California, 1986-1987. U.S. Geological Survey, Water-Resources Investigation Report 89-4102. 68 pp.

Setmire, J.G., R.A. Schroeder, J.N. Densmore, S.L. Goodbred, D.J. Audet, and W.R. Radke. 1993. Detailed study of water quality, bottom sediment, and biota associated with irrigation drainage in the Salton Sea area, California. U.S. Geological Survey. Water Resources Investigations Report 93-4014. 102 p.

Smith, G.J. and V.P. Anders. 1989. Toxic effects of boron on mallard reproduction. Environ. Toxicol. Chem. 8:943-950.

Stanley, T.R., G.J. Smith, D.J. Hoffman, G.H. Heinz, and R. Rosscoe. 1996. Effects of boron and selenium on mallard reproduction and duckling growth and survival. Environ. Toxicol. Chem. 15(7):1124-1132.

BORON CONCENTRATIONS IN WATERFOWL AT THE SALTON SEA

AND IMPLICATIONS FOR AVIAN IMPACTS

By: Carol A. Roberts
Divsion of Environmental Contaminants
Carlsbad Fish and Wildlife Office
U.S. Fish and Wildlife Service

March, 1999