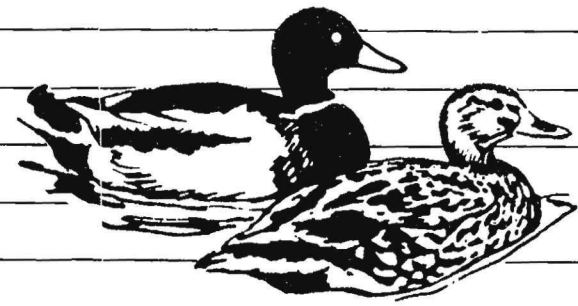
Research



Information bulletin

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Low Selenium in Waterfowl Wintering at Kern National Wildlife Refuge

Excessive levels of selenium (Se) have been linked to impaired reproduction and embryotoxicity in breeding waterbirds. Little is known, however, about Se accumulation in wintering waterfowl. I examined Se concentrations in northern pintails (*Anas acuta*) northern shovelers (*A. clypeata*), green-winged teals (*A. crecca*), and ruddy ducks (*Oxyura jamaicensis*) wintering in the southern San Joaquin Valley, California, to determine if freshwater wetlands reduce dietary Se exposure among wintering waterfowl. The wetlands included more than 2,800 ha of Se contaminated evaporation ponds (Figure); Kern National Wildlife Refuge (NWR), an uncontaminated freshwater area of about 1,200 ha; and small areas of private hunting clubs and flooded agricultural fields. Freshwater habitat provides both seeds (carbohydrate) and aquatic invertebrates (protein), whereas hypersaline evaporation ponds produce few seeds but many aquatic invertebrates.

I hypothesized that Se concentrations in waterfowl would reflect their mobility, foraging strategies, and habitat quality and availability. Northern pintails, northern shovelers and green-winged teals are highly mobile during the winter, whereas ruddy ducks are generally less mobile. Northern pintails and green-winged teals tend to forage principally on plant matter and should have lower concentrations of Se than northern shovelers and ruddy ducks that consume a high proportion of animal matter. Likewise, highly mobile species moving among all habitats (northern shovelers) should have lower Se concentrations than species with lower mobility (ruddy ducks) given similar foraging strategies.

Seasonal and Sex Differences in Selenium Concentrations Were Apparent in Breast but not Liver Tissue

I obtained breast and liver tissue samples of the four waterfowl species for Se analysis from birds taken by hunters during the 1988–89 hunting season on Kern NWR and from the same species shot on nearby evaporation ponds. After converting Se wet weight values to dry weights, I used the common log of each value to calculate geometric means for making comparisons of Se concentrations in tissues among species and between habitats. Separate ANOVAs were done for breast and liver tissue using a general linear models approach to assess the effects of species, sex, season, and habitat on mean Se concentrations. Significant main effects and interactions were followed up with Fisher's Protected LSD test and linear contrasts among the means to isolate specific differences. The results of the ANOVAs and subsequent analysis indicated significant differences among species within each habitat, and differences between habitats within each species (Table).

Among waterfowl from Kern NWR, Se concentrations in breast and liver tissue of northern pintails and green-winged teals were lower than in northern shovelers and ruddy ducks (Table). The Se concentration used by the California Department of Health Services to advise against human consumption—about 7.1 μg/g dry weight, assuming 72% moisture—was exceeded only by the breast tissue of male northern shovelers taken in October–November 1988 ($n = 6$). The result of the ANOVAs also indicated a significant sex by season interaction in which Se concentrations in breast tissues from males taken in October–November (early season) from Kern NWR were higher than in females taken in early season ($P = 0.018$) and in males taken in December–January (late season; $P < 0.001$). I did not detect a difference in Se concentration in breast tissue between females taken in early season and late season ($P = 0.568$) or between sexes during late season ($P = 0.395$). Concentrations of Se in breast tissue of northern pintails from Kern NWR were similar to those of wintering northern pintails from other freshwater areas (Tule Lake NWR; $\bar{x} = 1.71$ μg/g). Northern shovelers from Kern NWR contained about 1.7 times the Se concentrations of wintering northern shovelers from other freshwater areas (Suisun Marsh and Gray Lodge Wildlife Area; $\bar{x} = 1.8$ μg/g).

Concentrations of Se in breast tissue from both northern shovelers and ruddy ducks from Kern NWR were substantially lower than those collected in 1982 and 1983 ($\bar{x} = 7.22$ μg/g, $n = 9$, and $\bar{x} = 8.85$ μg/g, $n = 9$, respectively) from adjacent evaporation ponds . Selenium concentrations in breast tissue of northern pintails, green-winged teals, and ruddy ducks from Kern NWR were lower than those from evaporation ponds (Table). The same was true for Se in liver tissue from northern shovelers and ruddy ducks, but a lack of data prevented comparisons by habitat for Se in liver from northern pintails and green-winged teals (Table). Se in liver tissue of northern shovelers and ruddy ducks from evaporation ponds exceeded both the human health advisory level and levels associated with avian reproductive impairment (10 μg/g dry weight). Uptake and loss of Se by liver tissue is a rapid event (equilibrium with dietary concentrations can occur in 7 days), but occurs more slowly in muscle tissue. Thus, the long-term history of Se exposure is probably best reflected in avian breast tissue, whereas the short-term history is more accurately reflected in liver tissue.

Kern National Wildlife Refuge Reduces Contaminant Threat for Wintering Waterfowl

Before late October, waterfowl in the San Joaquin Valley forage in evaporation ponds or in flooded agricultural fields, the only available habitats and ones that principally produce aquatic invertebrates. Northern pintails and green-winged teals seem to forage preferentially in freshwater habitats despite movement among all available habitats. Behavioral observations on evaporation ponds suggest that wintering northern pintails use these sites primarily for resting, although time–activity budgets indicate feeding accounted for about 45% of all activities during winter and spring.

Several factors may cause northern pintails and green-winged teals to frequent evaporation ponds and forage there. First, the limited freshwater habitats may not provide sufficient food resources throughout the winter period. Waterfowl foraging in the moist-soil management area on Kern NWR may exceed the site's carrying capacity. Production of aquatic invertebrates in flooded agricultural fields declines after late November because of cooler water temperatures and the short duration of flooding, rendering the fields useless as foraging sites. Second, during late winter and spring waterfowl are probably attracted to the easily obtainable aquatic invertebrates in evaporation ponds to meet protein demands of migration and reproduction. Finally, hunting on freshwater sites may force birds to seek refuge on areas that receive little or no hunting pressure. With adequate high-quality freshwater habitats providing sufficient plant and animal matter to foraging birds, concentrations of Se in breast tissue of wintering northern pintails and green-winged teals should be near background levels wherever they are collected. Data presented here indicate otherwise in the San Joaquin Valley where concentrations of Se in breast tissue of northern pintails and green-winged teals from evaporation ponds exceeded those of birds from Kern NWR. This indicates that the underlying hypothesis of high mobility and preference for carbohydrates among wintering northern pintails and green-winged teals may be wrong. Conversely, the small amount of uncontaminated freshwater habitat that produces carbohydrate foods may be inadequate to support the dietary needs of northern pintails and green-winged teals, and the abundant aquatic invertebrates offered by evaporation ponds provide an irresistible, albeit less preferred, food for wintering birds. Furthermore, although high mobility should allow northern pintails and green-winged teals to freely choose among habitats, contaminated evaporation ponds provide most of the available habitat for wintering birds.

Northern shovelers use all habitats and do not seem to prefer either freshwater or evaporation ponds. Concentrations of Se in breast tissue of northern shovelers probably reflect an average dietary Se exposure among all habitats in the San Joaquin Valley. Although ruddy ducks are omnivorous, individuals tend to exhibit low mobility, indicating that Se concentrations in ruddy ducks generally reflect site-specific contaminant exposure. Ruddy ducks foraging in uncontaminated habitats are likely to exhibit low Se concentrations whereas those foraging in evaporation ponds are likely to

exhibit Se concentrations directly related to the degree of contamination.

Managing Water and Habitat Decreases Exposure to Selenium

Limited freshwater habitat in the San Joaquin Valley during fall and winter increases exposure of waterfowl to Se by requiring use of contaminated habitats. Furthermore, early spring removal of water from the freshwater habitats eliminates them as a source of uncontaminated aquatic invertebrates. The area of freshwater habitats and their duration of flooding should be increased by delivering water in August and retaining it longer into spring, providing uncontaminated habitat in critical late summer and late winter periods. Freshwater habitats should be managed to increase aquatic invertebrate production and provide sources of invertebrates other than evaporation ponds throughout the wintering period. Some freshwater habitats should be managed as sanctuary to further enhance their attraction to waterfowl. Management of freshwater habitats to match biological needs of wintering and migrating waterfowl can significantly alleviate Se exposure among waterfowl wintering in the San Joaquin Valley.

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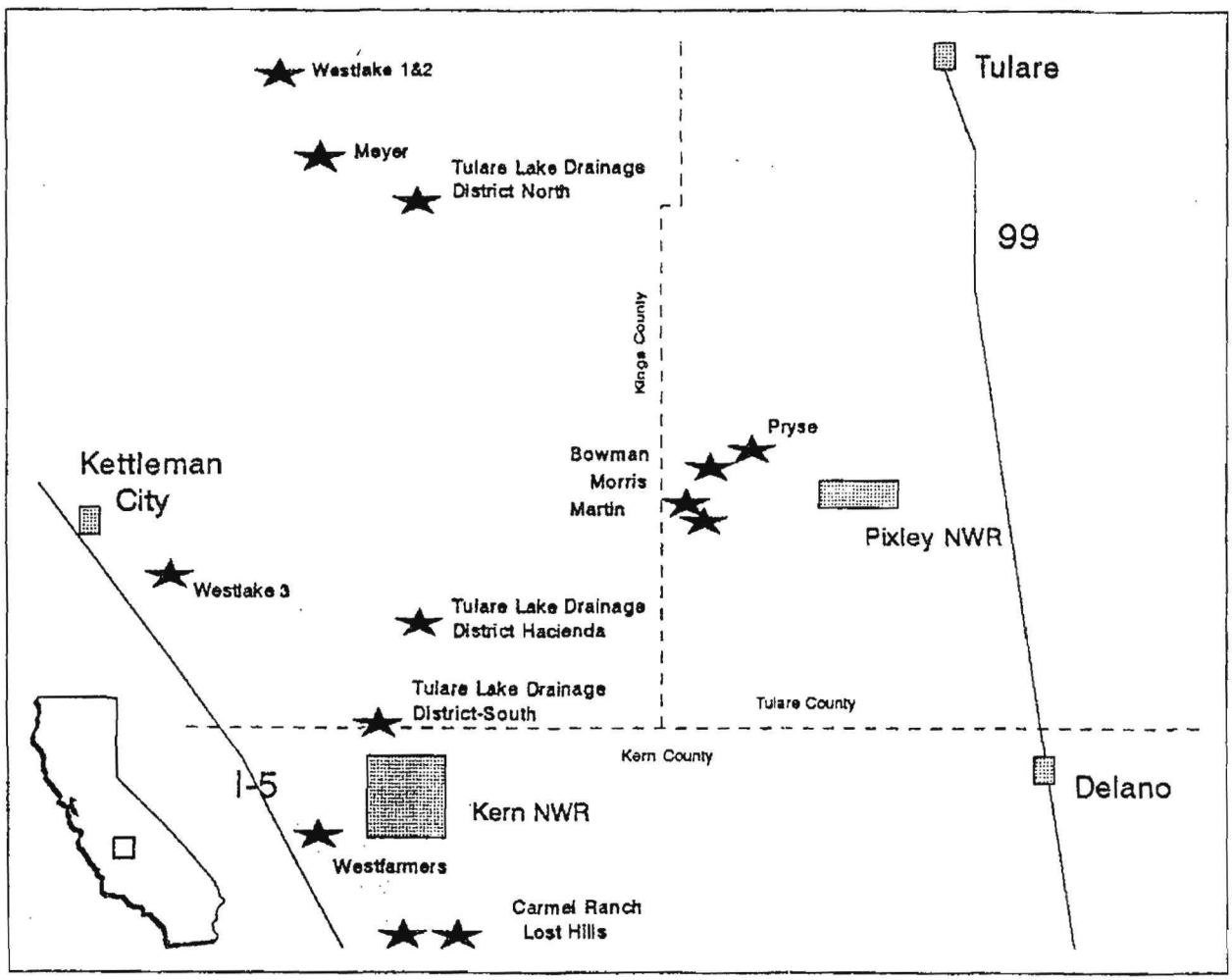

Figure. Kern National Wildlife Refuge and surrounding evaporation ponds.

Table. Concentrations of selenium in breast and liver tissue (μg/g dry weight) for waterfowl from Kern National Wildlife Refuge and adjacent evaporation ponds, September 1988–March 1989.[a]

	Breast[b]				Liver			
	Kern NWR		Evap pond		Kern NWR		Evap pond	
	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
Green-winged teal	1.39	20 A	4.66 A *	4	4.23	40 A		
Northern pintail	1.84	17 A	4.84 A *	7	4.84	28 A		
Northern shoveler	3.03	36 B	3.96 A	8	10.04	49 B	18.26 A *	13
Ruddy duck	3.56	17 B	9.62 B *	27	8.75	11 B	32.31 B *	27

[a]Column means followed by different letters indicate species differences within a habitat ($P < 0.05$). Row means followed by * indicate habitat differences within a species ($P < 0.0021$; General Linear Models ANOVA and Fisher's Protected LSD test).
[b]Only birds collected December or later because of seasonal differences within species of selenium concentrations in breast tissue.