17. Selenium Impacts to Terrestrial and Aquatic Organisms

SURPRISING DYNAMICS DURING ECOLOGICAL RECOVERY AFTER HEAVY METAL CONTAMINATION
Ferson, S. (Applied Biomathematics); J. Crutchfield (Carolina Power & Light)

The population of bluegill sunfish "Lepomis macrochirus" in part of a lake in North Carolina was decimated by toxicological and developmental effects of selenium leached from ash settling ponds. To forecast the potential recovery after cessation of heavy metal contamination, a demographic model was created for the bluegill population based on data collected from on-going biological monitoring at the lake. The model included density dependence which is known to be an important aspect of the life history of this species and used Monte Carlo methods to analyze the effect of natural environmental variability. The life history of the species revealed by analysis of the population model suggests that, if selenium poisoning were stopped, the population could recover to pre-impact abundances within two years. The increased abundance would be unevenly distributed among age groups, however. Following this increase in abundance, the biology predicts a population crash, especially among older year classes (which are prized by sport fishermen). This crash is due to the time-delayed effects of selenium on the population resulting from the strong non-linearity of density dependence in this species. The sharp increase in population size itself precipitates the crash. If this crash were not forecast in advance, its unanticipated occurrenc e could cause considerable consternation among managers, regulators and the interested public. This example shows that it can be important to predict ecological consequences to understand the nature and duration of biological recovery from toxicological insults. Without the understanding provided by the ecological analysis, the population decline would probably be completely misinterpreted as the failure of the mitigation program.

ARSENIC, MERCURY, SELENIUM, AND ORGANOCHLORINE COMPOUNDS IN INTERIOR LEAST TERN EGGS IN THE NORTHERN GREAT PLAINS STATES, 1992-1994
Allen, G.T.; S.H. Blackford
U.S. Fish and Wildlife Service Contaminant Report No R6-515M-97, 39 pp, 1997

EFFECT OF SULFATE LEVEL ON SELENIUM UPTAKE BY RUPPIA MARITIMA
Bailey, F.C.; A.W. Knight, R.S. Ogle; S.L. Klaine
Chemosphere, Vol 30 No 3, p 579-591, Feb 1995

SPECIATION OF SELENIUM IN THE MAMMALIAN ORGANISM
Behne, Dietrich; Christian Hammel; Doris Röthlein
The Analyst, Vol 123 No 5, p 871-873, 01 May 1998

THE ANTAGONISTIC EFFECT OF SELENIUM ON MERCURY UPTAKE BY FRESHWATER FISH
Belzile, Nelson (Dept. of Chemistry & Biochemistry, Laurentian Univ., Sudbury, ON. belzile@nickel.laurentian.ca); Yu-Wei Chen; John Gunn (Cooperative Freshwater Ecology Unit, Laurentian Univ., Sudbury, ON)
International Conference on Heavy Metals in the Environment, 6-10 August 2000, Ann Arbor, MI
Elsevier Science Publishers, Oxford, UK

The concentrations of Se and Hg were determined in muscles of two freshwater fish species, namely perch (*Perca flavescens*) and walleye (*Stizosedion vitreum*). Samples of various sizes were collected from ten lakes of Northern Ontario with various chemical and limnological nature. The correlation analysis revealed a clear and strong antagonistic effect between Se and Hg in muscles for both perch (r= - 0.790) and walleye (r = - 0.973), with the concentrations of Hg decreasing exponentially as Se increase. Total Se concentrations of the lakes were linearly correlated to Se in fish muscles. Hg concentrations in fish from lakes near the Sudbury smelters were well below average values for fish in boreal shield lakes of this region. To view papers/abstracts from the conference: http://www.sph.umich.edu/eih/heavymetals/TechnicalProgram.html

BIOACCUMULATION OF ORGANIC AND INORGANIC SELENIUM IN A LABORATORY FOOD CHAIN
Besser, J.M.; T.J. Canfield; T.W. La Point
Environmental Toxicology and Chemistry, Vol 121, p 57-72, 31 Jan 1993

Aquatic organisms accumulated selenium (Se) from inorganic and organic Se species via aqueous and food-chain exposure routes. The authors measured aqueous and food-chain Se bioaccumulation from selenate, selenite, and seleno-L-methionine in a laboratory food chain of algae (Chlamydomonas reinhardtii), daphnids (Daphnia magna), and fish (bluegill, Lepomis macrochirus). Selenium concentrations were monitored radiometrically with 75-Se-labeled compounds. All three organisms concentrated Se more strongly from aqueous selenomethionine than from either inorganic Se species. Bioconcentration factors estimated from 1 μg Se/L Se-methionine exposures were approximately 16,000 for algae, 200,000 for daphnids, and 5,000 for bluegills. Algae and daphnids concentrated Se more strongly from selenite than selenate whereas bluegills concentrated Se about equally from both inorganic species. Bioaccumulation of foodborne Se by daphnids and bluegills was similar in food chains dosed with different Se species. Daphnids and bluegills did not accumulate Se concentrations greater than those in their diet, except at very low dietary Se concentrations. Food-chain concentration factors (CFs) for daphnids decreased from near 1.0 to 0.5 with increases in algal Se concentrations, whereas CFs estimated from bluegill exposures averaged 0.5 over a range of foodborne Se concentrations. In exposures based on selenite, bluegills accumulated greater Se concentrations from food than from water.

TOXICITY AND ACCUMULATION OF SELENITE AND SELENATE IN THE UNICELLULAR MARINE ALGA CRICOSPHAERA ELONGATA.
Boisson, F.; M. Gnassia-Barelli; M. Romeo
Archives of Environmental Contamination and Toxicology, Vol 28 No 4, p 487-493, May 1995

HEAVY METAL AND SELENIUM CONCENTRATIONS IN FEATHERS OF EGRETS FROM BALIAND SULAWESI, INDONESIA
Burger, J.; M. Gochfeld

Archives of Environmental Contamination and Toxicology, Vol 32 No 2, p 217-221, 01 Feb 1997

Herons and egrets are ideal organisms to use as indicators of heavy metal exposure in an ecosystem because different species feed at different levels of the food chain and live in both coastal and inland habitats. This paper reports on the concentration of heavy metals and selenium in the feathers of cattle egrets Bubulcus ibis that were examined from nesting and roosting sites in Bali and Sulawesi, Indonesia, and in feathers of little egrets Egretta garzetta and intermediate egrets E. intermedia from the same colony in Bali. Mercury and manganese concentrations were significantly higher in cattle egrets from Bali compared to Sulawesi, but otherwise there were no significant differences. There were significant differences in lead, cadmium and mercury among the three egret species nesting on Bali: 1) the cadmium and mercury concentrations related to size and trophic level (insectivorous cattle egrets had the lowest concentrations, fish-eating intermediate egrets had the highest concentrations), and 2) cattle egrets had significantly lower concentrations of lead than the other two species. For cattle egrets, secondary flight feathers had significantly higher levels of cadmium and mercury, and lower levels of manganese, than mixed breast and tertiary feathers, reflecting temporal differences in exposure.

HEAVY METAL AND SELENIUM LEVELS IN FRANKLIN'S GULL (LARUS PIPIXCAN) PARENTS AND THEIR EGGS

Burger, J.; M. Gochfeld

Archives of Environmental Contamination and Toxicology, Vol 30 No 4, p 487-491, 01 May 1996

Lead, cadmium, mercury, chromium, selenium, and manganese concentrations were measured in the breast feathers of 25 pairs of Franklin's Gulls (Larus pipixcan) and in their eggs from a breeding colony at Agassiz National Wildlife Refuge in Northwestern Minnesota. Metal concentrations in eggs represent metals sequestered in the egg by females at the time of egg formation; while metal concentrations in parents represent concentrations of metals in the blood supply at the time of feather formation. There were no significant sexual differences in metal concentrations in feathers, assuming the male to be larger of each pair, but there were significant differences between the concentrations of metals in parents and their eggs. Eggs had significantly higher concentrations of selenium and chromium, but significantly lower concentrations of all other metals than the feathers of their parents. There were few significant correlations among metal concentrations within the egg or within the feather of females, but there were correlations for the feathers of males. Lead and cadmium in feathers were positively correlated for both males and females. Chromium concentrations in eggs were generally higher than reported in the literature. The concentrations in eggs and the feathers of females were positively correlated for mercury, and negatively correlated for chromium and manganese.

APPLICATION OF A HPLC-ETAAS COUPLING TO THE SELENIUM SPECIATION IN A FISH MUSCLE AFTER A MILD EXTRACTION

Cabon, M.; L. Badie; F. Pannier; N. Gilon; M. Potin-Gautier

Analusis, Vol 253, p M66, 30 Apr 1997

SELENIUM TOXICITY TO AQUATIC LIFE: AN ARGUMENT FOR SEDIMENT-BASED WATER QUALITY CRITERIA

Canton, S.P.; W.D. Van Derveer

Environmental Toxicology and Chemistry, Vol 16 No 6, p 1255-1259, 30 Jun 1997

A number of streams in Colorado were found to contain waterborne selenium concentrations that

consistently exceeded the current US EPA chronic criterion of 5 μg/L and often exceeded the acute criterion of 210 μg/L. Despite these elevated concentrations, no biological impact was observed. These findings led to a review of selenium exposure pathways in freshwater. The literature strongly indicates that chronic selenium toxicity can result from accumulation of selenium in the sediment, movement into the food chain, and resulting dietary uptake. Chronic toxicity does not appear to be strictly a result of waterborne selenium concentrations. In fact, dissolved selenium concentrations are a poor predictor of potential chronic toxicity to freshwater organisms, when evaluated with Hill's criteria for causal association. To develop a more reliable chronic waterborne criterion, a sediment-based method is needed to describe accurately potential chronic toxicity of selenium on a site-specific basis.

FFECTS OF SELENIUM DIOXIDE ON BLOOD AND FEMORAL BONE MARROW OF RATS
Chen, Chang-Yu; Te-Hsien Lin
Journal of Toxicology and Environmental Health Part A, Vol 59 No 7, p 553-560,

This study was undertaken to investigate the effects of selenium dioxide (SeO2) on rat blood and femoral bone-marrow oxidant mechanisms. Treatment with SeO2, 67 mu g Se/kg ip daily for 14 d, significantly decreased lipid peroxidation and the concentrations of Fe in serum and bone marrow. The concentrations of Se in serum and bone-marrow cells were significantly increased after SeO2 treatment. The activities of glutathione peroxidase (GPx)in blood and bone-marrow cells were markedly increased. The levels of oxyhemoglobin in blood were significantly increased, while the concentrations of methemoglobin were decreased after SeO2 administration. The fragility of erythrocytes membranes was significantly decreased in SeO2-treated rats compared to controls. Data suggest that treatment with a low dose of SeO2 may provide antioxidant nutrients to blood and bone marrow.

EFFECT OF DIETARY SELENIUM ON THE REPRODUCTIVE SUCCESS OF BLUEGILLS (LEPOMIS MACROCHIRUS)
Coyle, J.J.; D.R. Buckler; C.G. Ingersoll; J.F. Fairchild; T.W. May
Environmental Toxicology and Chemistry, Vol 123, p 551-565, 31 Mar 1993

The effects of dietary and waterborne selenium on the reproductive success of adult bluegills were evaluated in a chronic toxicity study. Before spawning, two-year-old bluegills were exposed for 60 d to six combinations of dietary and waterborne selenium. Mean seleno-L-methionine concentrations measured in the diet were 0.8 (control), 4.6, 8.5, 16.8, and 33.3 μg/g. Waterborne selenium was supplied as a 6:1 mixture of selenate and selenite. Nominal water-borne selenium exposure concentration was 10μg/L in all exposures except the control. Morphological measurements of adult fish, including length, weight, condition factor, and Gonado Somatic Index, were measured at days 60 and 140 of exposure. Reproductive indicators, including spawning frequency, number of eggs per spawn, percentage of hatch, and survival of resulting fry for 30 d after hatch were monitored during the 11-week spawning period. Selenium concentrations were determined in adult fish, eggs, and 30d-old fry. Only fry were significantly affected. Survival was severely reduced in fry of parents exposed to 10μg/L waterborne selenium in combination with dietary exposure of 33.3 μg/g seleno-L- methionine. These results support field observations that indicate food-chain accumulation of selenium can severely reduce reproductive success of bluegills.

TISSUE DISTRIBUTION OF MERCURY AND SELENIUM IN MINNOWS, PHOXINUS PHOXINUS
Cuvin-Aralar, M.L.; R.W. Furness
Bulletin of Environmental Contamination and Toxicology, Vol 455, p 775-782, 30 Nov 1990

TOXICITY AND BIOACCUMULATION OF SELENIUM TO A THREE-TROPHIC LEVEL FOOD CHAIN

Dobbs, M.G; D.S. Cherry; J. Cairns Jr.

Environmental Toxicology and Chemistry, Vol 15 No 3, p 340-347, 31 Mar 1996

Three species, Chlorella vulgaris, Brachionus calyciflorus, and Pimephales promelas, were exposed to selenate for 25 d in a three-trophic level test system. The organisms were linked in a continuous flow-through system in separate vessels, with each organisms feeding on the trophic level below it. These organisms were continually exposed for 25 d to 0, 110.3, 207.7, and 396.1 μg/L total recoverable selenium (Se) from selenate in natural creek water supplemented with nutrients to sustain algal growth. In an initial algal screening test, growth rates were reduced at 81.7 and 1,053.7 μg/L, with no effect at 8.5 μg/L. In the trophic test, algal populations showed evidence of reduced growth rates at 207.7 and 386.1 μg/L, but not at 110.3 μg/L. Rotifer population standing crop (measured as dry weight) was significantly reduced at 207.7 and 396.1 μg/L by day 4, and declined to below detection by day 7 at these treatments. Fathead minnow growth was impaired after 7 d at the 207.7 and 396.1 μg/L levels, with 100% mortality by day 16. A reduction in rotifers and fish biomass was also apparent at the 110.3 μg/L level after day 20. The amount of Se in whole organisms was measured throughout the experiment. Bioconcentration factors were found to be dependent on the species, treatment level, and length of exposure period, and they ranged between 100 and 1,000.

PB, CD, AS, AND SE CONCENTRATIONS IN LIVERS OF DEAD WILD BIRDS FROM THE EBRO DELTA, SPAIN

Guitart, R.; R. Mateo; S. Cerradelo; P. Puig-Casado; M. Torra; J.To-Figueras

Bulletin of Environmental Contamination and Toxicology, Vol 524, p 523-529, 31Aug 1994

Wild bird populations are susceptible to the environmental presence of toxic elements and substances, especially those that are non-degradable and tend to concentrate through the food chain. Monitoring of such substances in selected bird species could be useful to evaluate the health condition of the species involved and to assess contamination in the ecosystem. One of the most important wild bird sanctuaries of Europe, the Ebro Delta, is situated in NE Spain. The Ebro Delta is an alluvial plain of about 32,000 ha. Because of its special hydrological conditions and geographical situation, the Ebro Delta supports an important and diverse bird population, estimated at 180,000 in the winter period, constituting 311 different species. Most of the Ebro Delta's surface is dedicated to agriculture, principally rice, also serving as an excellent wild bird habitat. Accordingly, agricultural pesticides could be a major problem for wildlife. But in the last few decades the Ebro River and the Tarragona coast have also undergone considerable industrial development. The area is now facing environmental threats by industrial activities, and the ecosystem is becoming contaminated with heavy metals, petroleum hydrocarbons and PCBS. Heavy metal concentrations in marine organisms have been reported, but metal and metalloid concentrations in birds have not been available. This study monitors lead (Pb), cadmium (Cd), arsenic (As) and selenium (Se) concentrations in bird livers from diverse trophic levels in the Ebro Delta. Pb, Cd, and As are well recognized as toxic elements, while Se, although causing well known deleterious effects for humans and domestic animals, has only recently been recognized as toxic for aquatic birds. The determination of contaminant loads in several avian species would be useful to control and prevent, when possible, pathological conditions derived from toxic levels of these contaminants for wild bird populations living in the Ebro Delta.

HAZARD ASSESSMENT OF INORGANICS TO THREE ENDANGERED FISH IN THE GREEN RIVER, UTAH
Hamilton, S.J.
Ecotoxicology and Environmental Safety, Vol 30 No 2, p 134-142, Mar 1995

MECHANISMS OF SELENIUM METHYLATION AND TOXICITY IN MICE TREATED WITH SELENOCYSTINE
Hasegawa, Tatsuya; Makoto Mihara; K. Nakamuro; Yasuyoshi Sayato
Archives of Toxicology, Vol 1 No 1/2, 25 Nov 1996

Mechanisms of selenium methylation and toxicity were investigated in the liver of ICR male mice treated with selenocystine. To elucidate the selenium methylation mechanism, animals received a single oral administration of selenocystine (Se-Cys; 5, 10, 20, 30, 40, or 50?mg/kg). In the liver, both accumulation of total selenium and production of trimethylselenonium (TMSe) as the end-product of methylation were increased by the dose of Se-Cys. A negative correlation was found between production of TMSe and level of S-adenosylmethionine (SAM) as methyl donor. The relationship between Se-Cys toxicity and selenium methylation was determined by giving mice repeated oral administration of Se-Cys (10 or 20?mg/kg) for 10 days. The animals exposed only to the high dose showed a significant rise of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) activities in plasma. Urinary total selenium increased with Se-Cys dose. TMSe content in urine represented 85% of total selenium at the low dose and 25% at the high dose. The potential of Se-methylation and activity of methionine adenosyltransferase, the enzyme responsible for SAM synthesis, and the level of SAM in the liver were determined. The high dose resulted in inactivation of Se-methylation and decrease in SAM level due to the inhibition of methionine adenosyltransferase activity. To learn whether hepatic toxicity is induced by depressing selenium methylation ability, mice were injected intraperitoneally with periodate-oxidized adenosine (100?mmol/kg), a known potent inhibitor of the SAM-dependent methyltransferase, at 30?min before oral treatment of Se-Cys (10, 20, or 50?mg/kg). Liver toxicity induced by selenocystine was enhanced by inhibition of selenium methylation. These results suggest that TMSe was produced by SAM-dependent methyltransferases, which are identical with those involved in the methylation of inorganic selenium compounds such as selenite, in the liver of mice orally administered Se-Cys. Depression of selenium methylation ability resulting from inactivation of methionine adenosyltransferase and Se-methylation via enzymic reaction was also found in mice following repeated oral administration of a toxic dose of Se-Cys. The excess selenides accumulating during the depression of selenium methylation ability may be involved in the liver toxicity caused by Se-Cys.

SELENIUM METABOLITE LEVELS IN HUMAN URINE AFTER DOSING SELENIUM IN DIFFERENT CHEMICAL FORMS
Hasunuma, Ryoich; Moriz Tsuda; Tada Ogawa; Yasuhiro Kawanishi
Bulletin of Environmental Contamination and Toxicology, Vol 51 No 5, p 756-763, 30 Nov 1993

It has been well known that selenium in marine fish such as tuna and swordfish protects the toxicity of methylmercury in vivo. The protective potency might depend on the chemical forms of selenium in the meat of marine fish sebastes and sperm whale. Little has been revealed, however, on the chemical forms of selenium in the meat of these animals or the selenium metabolites in urine, because the amount of the element is very scarce. Urine is the major excretory route for selenium. The chemical forms of urinary selenium may reflect the metabolism of the element. We have developed methodology for analysis of selenium-containing components in human urine. Using this method, we have observed the time courses of

excretory levels of urinary selenium components after a single dose of selenium as selenious acid, selenomethionine, trimethylselenonium ion or tuna meat.

RE-EXPOSURE OF MALLARDS TO SELENIUM AFTER CHRONIC EXPOSURE
Heinz, G.H.
Environmental Toxicology and Chemistry, Vol 129, p 1691-1694, 30 Sep 1993

Adult male mallards (Anas platyrhynchos) were fed a control diet or a diet containing 15 ppm selenium as seleno-D,L-methionine for 21 weeks. After this initial exposure, the mallards were fed untreated food for 12 weeks, then were re-exposed to selenium at 100 ppm for five weeks. During re-exposure to 100 ppm selenium, the birds that had previously been exposed to 15 ppm selenium and those that had not previously been exposed did not differ in percentage of mortality, weight loss in survivors, selenium concentrations in the livers of survivors, or selenium concentrations in the livers of birds that died. When the data from the birds that had previously been exposed to 15 ppm selenium were combined in the livers of birds that had died on the 100-ppm selenium treatment did not differ from the concentrations in the livers of birds that had survived.

TOXICITY OF SELENO-L-METHIONINE, SELENO-DL-METHIONINE, HIGH SELENIUM WHEAT, AND SELENIZED YEAST TO MALLARD DUCKLINGS
Heinz, G.H.; D.J. Hoffman; L.J. LeCaptain
Archives of Environmental Contamination and Toxicology, Vol 30 No 1, p 93-99, 01 Jan 1996

The toxicity of four chemical forms of selenium (seleno-L-methionine, seleno-DL-methionine, selenized yeast, and high selenium wheat) was compared in day-old mallard ducklings (Anas platyrhynchos). In the first experiment, in which the basal diet was 75% wheat, survival after 2 weeks was lower for ducklings fed 30 mg/g selenium as seleno-L-methionine (36%) than for ducklings fed 30 mg/g selenium as seleno-DL-methionine (100%) or 30 mg/g selenium from high selenium yeast (88%). The concentration of selenium at 2 weeks in the livers of survivors was similar for ducklings fed 15 mg/g selenium as seleno-DL-methionine (12 mg/g, wet weight), seleno-L-methionine (11 mg/g), and high selenium wheat (11 mg/g), but was lower when the selenium came from selenized yeast (6.2mg/g). When fed 30 mg/g selenium from the various sources, the selenium concentrations in liver were 20 mg/g for seleno-DL-methionine, 19 mg/g for seleno-L-methionine, and 9.9 mg/g for selenized yeast. In a second experiment, in which the basal diet was a commercial duck feed, survival after 2 weeks was 100% in ducklings fed 30 mg/g selenium as seleno-DL-methionine, seleno-L-methionine, or selenized yeast. Selenium concentrations in liver were similar for ducklings fed the 30-mg/g selenium diets as the DL or L forms of selenomethionine (27 and 25 mg/g), but lower for ducklings fed selenized yeast (13 mg/g). The greater toxicity of the L form of selenomethionine was probably related to the palatability or nutritional nature of the wheat-based diet used in experiment 1, but the exact reason for the difference between the DL and L forms is unknown. Biologically incorporated selenium, derived from high selenium wheat, was no more toxic than selenium derived from the two purified forms of selenomethionine, and the selenium in selenized yeast was not as toxic as that in the two forms of selenomethionine.

EXCESS SELENIUM INCREASES CA^{++}-INDUCED CLOTTING TIMES IN CHICKS AND RATS
Herz, W.C.; G.F. Combs Jr.
FASEB Journal (Federation of American Societies for Experimental Biology), Vol 54, p A714, 11 Mar

1991

Calcium (Ca^{++})-induced clotting times (i.e., prothrombin times, PT times) in young White Leghorn chickens and male weanling Sprague Dawley rats were shown to be elevated in animals fed diets for 20-30 days containing excess Se. Clotting times of chicks were prolonged from those of controls in animals fed either deficient or excess Se, although all dietary treatment groups showed comparable concentrations of total plasma protein. Rats showed significantly prolonged PT times when fed Se at either 5 ppm or 10 ppm. The plasma activities of certain enzymes of hepatic origin (alanine aminotransferase, aspartate aminotransferase, ã-glutamyl transpeptidase) in rats fed excess Se were comparable to those of controls, despite the increase in the PT times. Body weights and liver weights were significantly depressed in those animals only at the 10 ppm Se level. These results demonstrate increased PT times in both chicks and rats. In each species, this effect is independent of feed intake and body weight, and is apparent at levels of Se intake that do not affect other indicators of hepatic damage. Therefore, prolonged PT time may be an early indicator of sub-acute selenosis.

ASSOCIATION OF MERCURY AND SELENIUM WITH ALTERED GLUTATHIONE METABOLISM AND OXIDATIVE STRESS IN DIVING DUCKS FROM THE SAN FRANCISCO BAY REGION, USA

Hoffman, D.J; G.W. Pendleton; H.M. Ohlendorf; C.M. Marn

Environmental Toxicology and Chemistry, Vol 17 No 2, p 167-172, 28 Feb 1998

Adult male greater scaup (Aythya marila), surf scoters (Melanitta perspicillata), and ruddy ducks (Oxyura jamaicensis) were collected from Suisun Bay and coastal Tomales Bay in the greater San Francisco Bay area to assess exposure to inorganic contaminants. Hepatic Se concentrations were highest in greater scaup and surf scoters in Suisun Bay, whereas hepatic Hg was highest in greater scaup and surf scoters from Tomales Bay. Hepatic Se and Hg were lower in ruddy ducks and did not differ between locations. It is concluded that measurement of associated enzymes in conjunction with thiol status may be a useful bioindicator to discriminate between Hg and Se effects. Concentrations of Hg and Se and the above variables affected have been associated with adverse effects on reproduction and neurological function in experimental studies with mallards.

TOXICITY AND OXIDATIVE STRESS OF DIFFERENT FORMS OF ORGANIC SELENIUM AND DIETARY PROTEIN IN MALLARD DUCKLINGS

Hoffman, D.J.; G.H. Heinz; L.J. LeCaptain; J.D. Eisemann; G.W. Pendleton

Archives of Environmental Contamination and Toxicology, Vol 31 No 1, p 120-127, 01 Jul 1996

Concentrations of over 100 ppm (mg/kg) selenium (Se) have been found in aquatic plants and insects associated with irrigation drainwater and toxicity to fish and wildlife. Composition of diet for wild ducklings can vary in selenium-contaminated environments. Earlier studies have compared toxicities and oxidative stress of Se as selenite to those of seleno-DL-methionine (DL) in mallards (Anas platyrhynchos). This study compares DL, seleno-L-methionine (L), selenized yeast (Y) and selenized wheat (W). Day-old mallard ducklings received an untreated diet (controls) containing 75% wheat (22% protein) or the same diet containing 15 or 30 ppm Se in the above forms except for 30 ppm Se as W. After 2 weeks, blood and liver samples were collected for biochemical assays and Se analysis. All forms of selenium caused significant increases in plasma and hepatic glutathione peroxidase activities. Se as L at 30 ppm in the diet was the most toxic form, resulting in high mortality (64%) and impaired growth (>50%) in survivors and the greatest increase in ratio of oxidized to reduced hepatic glutathione (GSH). Se as both L and DL decreased the concentrations of hepatic GSH and total thiols. Se as Y accumulated the least in liver

(approximately 50% of other forms) and had less effect on GSH and total thiols. In a second experiment, in which the basal diet was a commercial duck feed (22% protein), survival was not affected by 30 ppm Se as DL, L, or Y and oxidative effects on GSH metabolism were less pronounced than with the wheat diet.

ENVIRONMENTAL CONTAMINANTS IN EGGS OF CALIFORNIA LEAST TERNS (STERNA ANTILLARUM BROWNI)

Hothem, R.L.;S.G. Zador

Bulletin of Environmental Contamination and Toxicology, Vol 55 No 5, p 658-665, 30 Nov 1995

A severe decline in the coastal breeding population of California least terns (Sterna antillarum browni) in California and Baja California prompted both State and Federal governments to designate it an endangered species in 1970. Significant losses of nesting and feeding habitat have contributed greatly to the decline of this subspecies. However, environmental contaminants, such as organochlorine compounds and metals, may also have contributed to the decline. California least terns are primarily piscivorous during the nesting period, feeding predominantly on jack-smelt, topsmelt, and northern anchovy. Topsmelt had the highest levels of DDE (p,p'-DDE) (up to 3 μg/g wet wt) of fish collected from San Diego Bay. Eggs of Caspian terns (S. caspia) from that study contained up to 56 μg/g DDE, and DDE was associated with a reduction in eggshell thickness as determined by the thickness index. In addition to shell deficiencies, organochlorines can also cause reduced egg production, aberrant incubation behavior, delayed ovulation, embryotoxicosis, and mortality of chicks and adults. Mercury (Hg) and selenium (Se) have caused decreased hatchability, altered nesting behavior, and embryotoxicosis in birds in field and laboratory studies. Our objective was to evaluate the role of contaminants in the decline of California least terns.

IN VITRO EFFECT OF MERCURIC CHLORIDE AND SODIUM SELENITE ON CHEMILUMINESCENT RESPONSE OF PRONEPHROS CELLS ISOLATED FROM TILAPIA, OREOCHROMIS AUREUS

Low, K.W.; Y.M. Sin

Bulletin of Environmental Contamination and Toxicology, Vol 556, p 909-914, 31 Dec 1995

Phagocytosis is a basic immunological function of mononuclear phagocytes and polymorphonuclear leukocytes. This process is a major defense mechanism in fish which involves recognition and killing of pathogenic microorganisms. It has been reported that phagocytic cells consume more oxygen and release several reactive oxygen species (ROS) during phagocytosis. This “respiratory burst” was first quantified by measuring the chemiluminescence (CL) emitted from human polymorphonuclear leukocytes and later in fish phagocytes. The oxygen intermediates responsible for this CL reaction include O2-, OH, and H2O2 which are also the major bactericidal agents in phagocytes oxygen-dependent killing process. Therefore, CL response can be used as an indicator of phagocytosis. This study is designed to examine the individual effects of mercury and selenium and also their possible interaction on CL response of fish pronephros phagocytes, because a defect in phagocytosis may predispose fish to diseases.

COMPARATIVE TOXICITY OF SELENATE, SELENITE, SELENO-DL-METHIONINE AND SELENO-DL- CYSTINE TO DAPHNIA MAGNA

Maier, K.J.; C.G. Foe; A.W. Knight

Environmental Toxicology and Chemistry, Vol 124, p 755-763, 30 Apr 1993

Elevated concentrations of the trace element selenium (Se) have resulted in the degradation of

several aquatic ecosystems. This study evaluated the comparative toxicity of several aqueous chemical species of selenium to an aquatic cladoceran, Daphnia magna. Responses to mixtures of these selenium forms, varying the sulfate concentration, were also examined. Initial experiments compared the toxicity of aqueous forms of selenate, selenite, seleno-DL-methionine, and seleno- DL-cystine to neonate Daphnia magna, resulting in 4-h LC50 values of 2.84, 0.55, 0.31, and 2.01 mg Se per liter, respectively. Immobilization was an acute sublethal response observed during exposure to the organic selenium forms only. The 48-h IC50 values were 0.045 and 0.52 mg Se per liter for seleno-DL-methionine and seleno-DL-cystine, respectively. Evaluation of the invertebrate response to various combinations of selenate, selenite, and seleno-DL-methionine demonstrated that the toxicities of these forms of selenium are additive. Increasing the concentration of sulfate decreased, varied, and left unaffected the toxicities of selenate, selenite, and seleno-DL-methionine, respectively. These
results indicate that both the chemical form of selenium and the sulfate concentration can influence the toxicity of selenium.

FACTORS CONTROLLING THE BIOACCUMULATION OF MERCURY, METHYLMERCURY, ARSENIC, SELENIUM, AND CADMIUM BY FRESHWATER INVERTEBRATES AND FISH
Mason, R.P.; J.-M. Laporte; S. Andres
Archives of Environmental Contamination and Toxicology, Vol 38 No 3, p 283-297, 01 Apr 2000

Concentrations of mercury (Hg), methylmercury (MMHg), arsenic (As), selenium (Se), and cadmium (Cd) were measured in atmospheric deposition, stream water, and biota in two streams in western Maryland. Overall, concentrations were slightly higher in the water of the lower pH Herrington Creek tributary (HRCT). Bioaccumulation factors were also higher for HRCT compared to Blacklick Run (BLK). MMHg concentrations in biota increased with trophic level and essentially all the Hg was as MMHg in predatory insects and insectivorous/carnivorous fish. Thus, the overall trophic status of the organism was indicated by the %MMHg in its tissues. Levels of As, Se, Cd, and Hg, however, decreased with increasing trophic level. Adsorption of As to the exoskeleton of invertebrates appears to be an important accumulation mechanism. MMHg was distributed evenly throughout crayfish and fish organs, whereas As, Se, Cd, and Hg were found in higher concentrations in detoxifying organs. Concentrations in biota in this study were somewhat elevated compared to other rural sites, but were less than those of point source-contaminated sites. Overall, as atmospheric inputs to the two watersheds were similar, the results of this study show the importance of water chemistry in determining the bioaccumulation of the metals and metalloids into insects. Subsequent transfer to higher trophic levels is related to both the ability of the organisms to depurate and the mode of accumulation, either directly from water or from food.

THE GEOCHEMISTRY AND BIOGEOCHEMISTRY OF SELENIUM IN RELATION TO ITS DEFICIENCY AND TOXICITY IN ANIMALS
Meyer, Roland D.; Richard G. Burau
Selenium in the Environment: Essential Nutrient, Potential Toxicant
M. Dekker, New York. ISBN: 0824789938. p 38-41, c1994

BIOGEOCHEMICAL INTERACTIONS AFFECTING HEPATIC TRACE ELEMENT LEVELS IN AQUATIC BIRDS
Moeller, G.
Environmental Toxicology and Chemistry, Vol 15 No 7, p 1025-1033, 31 Jul 1996

Knowledge of elemental interactions is important to the toxicological assessment of wildlife in the geochemical environment. This study determines the concentrations of Al, As, B, Ba, Be, Cd, Cr, Cu, Fe, Pb, Li, Mg, Mn, Hg, Mo, Ni, Se, Ag, V, and Zn in aquatic bird liver, fish liver, whole bivalves, insects, and waters in several aquatic ecosystems in northern California. There is evidence of strong in vivo and environmental interactions, including the observation of manganese as a possible cofactor or indicator in selenium bioaccumulation. The nearest neighbor selenium correlation in aquatic bird liver tissue that results from this work is Cd-Mn-Se-Hg-As. The correlation of liver selenium to manganese in vivo and the result that the majority of the variance in liver selenium concentration is contained in the manganese term of the regression model relating Se to Cd, Mn, and Hg is new knowledge in the study of aquatic birds. A linear relationship between liver selenium and environmental manganese (water and sediment) is found in the data, suggesting a water chemistry compartmentalization or activation of toxicants. Alternatively, the hepatic concentrations of selenium, manganese, and iron suggest induction of enzymes in response to oxidative stress.

SELENIUM, BORON, AND HEAVY METALS IN BIRDS FROM THE MEXICALI VALLEY, BAJA CALIFORNIA, MEXICO
Mora, M.A.; D.W. Anderson
Bulletin of Environmental Contamination and Toxicology, Vol 54 No 2, p 198-206, Feb 1995

TOXICITY OF ARSENIC, MOLYBDENUM AND SELENIUM COMBINATIONS TO CERIODAPHNIA DUBIA
Naddy, R.B. ; T.W. La Point; S.J. Klaine
Environmental Toxicology and Chemistry, Vol 142, p 329-336, 28 Feb 1995

Previous research done on the effects of contaminant mixtures has been evaluated primarily by using acute exposures. While this was an important initial step, characterizing the effects of chronic exposures of these mixtures is more environmentally pragmatic. This study examined the sublethal interactive effects of arsenic (As), molybdenum (Mo), and selenium (Se) on Ceriodaphnia dubia using the three-brood static renewal toxicity test. A complete factorial design experiment using four levels (zero, IC12.5, IC25, and IC50 values) of each metal was performed to investigate the binary and tertiary interactions of these metals on C. Dubia survival and fecundity. Results indicate three-way interactive effects in survival and fecundity with the strongest effect exhibited by Se. Molybdenum and As in binary combinations appear to be strongly antagonistic in their effects on C. dubia, even at their respective IC50 concentrations. However, generally the addition of Se to As-Mo mixtures significantly reduced survival and reproduction. The IC50 concentrations of either Mo or Se significantly reduced fecundity in all binary and tertiary mixtures. All tertiary metal mixtures, except the combination of the IC12.5 concentrations of each metal, significantly reduced C. dubia fecundity.

DETAILED STUDY OF SELENIUM IN SOIL, WATER, BOTTOM SEDIMENT, AND BIOTA IN THE SUN RIVER IRRIGATION PROJECT, FREEZOUT LAKE WILDLIFE MANAGEMENT AREA, AND BENTON LAKE NATIONAL WILDLIFE REFUGE, WEST-CENTRAL MONTANA, 1990-92
Nimick, D.A.; J.H. Lambing; D.U. Palawski; J.C. Malloy, U.S. Geological Survey, Helena, MT
USGS Water-Resources Investigations Report 95-4170, 120 pp, 1996

SELENIUM BIOACCUMULATION IN AQUATIC ECOSYSTEMS: 1. EFFECTS OF SULFATE ON THE UPTAKE AND TOXICITY OF SELENATE IN DAPHNIA MAGNA
Ogle, R.S.; A.W. Knight
Archives of Environmental Contamination and Toxicology, Vol 30 No 2, p 274-279, 01 Feb 1996

Selenium contamination and toxicity have been reported for aquatic ecosystems across the United States. Because waterborne selenium concentrations in natural systems are seldom high enough to be directly toxic, it has been concluded that bioaccumulation of selenium is causing observed toxicity problems. As a result, information regarding the bioaccumulation processes of selenium in aquatic organisms is necessary for appropriate management and remediation of selenium in aquatic ecosystems. Studies of selenium bioaccumulation in bacteria, fungi, and algae have indicated that selenate and sulfate compete for uptake via a common mechanism. However, such competitive interactions have not been examined in higher, multi-cellular organisms. To address this, we conducted
experiments to determine how changes in ambient sulfate concentrations affect the uptake of selenate in the freshwater crustacean Daphnia magna. D. magna were exposed to waterborne selenate concentrations ranging from control to 500 mg/L Se with varying concentrations of sulfate ranging from 0 mg/L to concentrations equivalent to EPA "very hard" water. At the higher concentrations of selenate, selenium uptake increased significantly as sulfate concentrations decreased. No toxicity was observed except at the 500 mg/L Se and "no sulfate" treatment, where virtually all of the daphnids died within 72 h.

SELENIUM TOXICITY IN WATERFOWL: THE KESTERSON EXPERIENCE
Ohlendorf, Harry M.
Selenium in the Environment: Essential Nutrient, Potential Toxicant
M. Dekker, New York. ISBN: 0824789938. p 11-19, c1994

BIOACCUMULATION OF SELENIUM IN BIRDS AT KESTERSON RESERVOIR, CALIFORNIA
Ohlendorf, H.M.; R.L. Hothem; C.M. Bunck; K.C. Marois
Archives of Environmental Contamination & Toxicology, Vol 19 No 4, p 495-507, 1990

SELENIUM INDUCED LIPID PEROXIDATION IN HEART TISSUES OF CHICK EMBRYOS
Padmaja, K.; B.V. Somasekharaiah; A.R.K. Prasad
Bulletin of Environmental Contamination and Toxicology, Vol , p 401-408, 30 Sep 1993

During the past three decades research has been carried out to elucidate the role of free radicals and reactive oxygen species play in various pathophysiological processes. Membranes of subcellular organelles contain relatively high concentrations of polyunsaturated lipids as well as hemoproteins which are strong catalysts of lipid peroxidation. Lipid peroxides (LPO) destroy membrane integrity and decrease membrane fluidity and elasticity. Selenium is known both as an important essential trace element and an environmental pollutant. Selenium has many uses in the industries. The main source of selenium for the mammalian organism is food (from the soil into the vegetables and grain) and to a lesser extent, drinking water. A number of syndromes of selenium toxicity in animals have been described. Selenium is regarded as the most important biological antioxidant. The antioxidant function of selenium is linked to the activity of seleno enzyme glutathione peroxidase (GPx), which catalyses
the reduction of hydroperoxides. The antioxidant enzymes like superoxide dismutase (SOD) reduce superoxide radicals to H2O2 which inturn is preferential oxidation of glutathione by peroxides is catalysed by GPx. The oxidized glutathione is then reduced by glutathione reductase (GR) and maintains the reduced glutathione levels in the system in a cyclic manner. Further, glutathione transferase (GST) catalyses the

transformation of a wide variety of electrophilic compounds to less toxic compounds by conjugating them to GSH. The present study evaluated the biochemical basis of selenium induced lipid peroxidative damage to heart tissues in check embryos and the role of antioxidant enzymes like GPx, GST, GR, SOD and CAT.

SELENIUM AND BORON IN AQUATIC BIRDS FROM CENTRAL CALIFORNIA
Paveglio, F.P.; C.M. Bunck; G.H. Heinz
Journal of Wildlife Management, Vol 56 No 1, p 31-42, 1992

MONITORING OF SELENIUM CONCENTRATIONS IN BIOTA FROM THE KENDRICK RECLAMATION PROJECT, NATRONA COUNTY, WYOMING, 1992- 1996
Ramirez, P. Jr.; K. Dickerson, Cheyenne, WY
U.S. Fish and Wildlife Service Contaminant Report No R6-714C-99, 16 pp, 1998

Selenium is bioaccumulating in fish and aquatic birds inhabiting the Kendrick Reclamation Project (Kendrick) in Natrona County, Wyoming as a result of mobilization associated with irrigation return flows. Field studies conducted in the 1980's by the U.S. Geological Survey (Survey) and the U.S. Fish and Wildlife Service (Service) as part of the Department of Interior's National Irrigation Water Quality Program (NIWQP) revealed elevated selenium concentrations in water, sediment and biota at Kendrick and immediately downstream in the North Platte River. Selenium concentrations found in biota exceeded levels known to cause mortality and embryonic deformities in birds and impaired reproduction in fish. Additionally, reduced hatchability was documented in nesting aquatic birds. The report is available at http://mountain-prairie.fws.gov/contaminants/papers/kendrick.pdf

SELENIUM IN FISH AND THE AQUATIC BIRD FOOD CHAIN, KENDRICK RECLAMATION PROJECT, NATRONA COUNTY, WYOMING
Ramirez, P. Jr.; M. Jennings; K. Dickerson
Annual Summer Symposium of American Water Resource Association: Effects of Human-Induced Changes on Hydrologic Systems, 26-29 June 1994, Jackson, WY. p 1043-1053, 1994

SELENIUM IN AQUATIC BIRDS NESTING IN THE KENDRICK RECLAMATION PROJECT, NATRONA COUNTY, WYOMING: APPARENT IMPACTS FROM IRRIGATION DRAINWATER
Ramirez, P. Jr.; G.T. Allen; J. Malloy
Planning, Rehabilitation and Treatment of Disturbed Lands, Sixth Billings Symposium, Billings, MT Montana State Univ. Bozeman, MT. Reclamation Research Unit Pub No 9301, 1993

THE INFLUENCE OF PH AND MEDIA COMPOSITION ON THE UPTAKE OF INORGANIC SELENIUM BY CHLAMYDOMONAS REINHARDTII
Riedel, G.F.; J.G. Sanders
Environmental Toxicology and Chemistry, Vol 159, p 1577-1583, 30 Sep 1996

The uptake of inorganic selenium species, selenate and selenite, by the green alga Chlamydomonas reinhardtii Dang was examined as a function of pH over the range 5 to 9 and in media with varying concentrations of major ions and nutrients using 75-Se as a radiotracer. Little difference was noted in the uptake of selenate as a function of pH, with the maximum uptake occurring at pH 8; however, selenite

uptake increased substantially at the lower pH values. Selenate uptake was significantly decreased by higher sulfate concentrations and increased significantly by calcium, magnesium, and ammonium. Selenite uptake was significantly increased when the phosphate concentrations in the media were reduced. The results of these experiments demonstrate that varying
water chemistry may significantly affect the uptake of inorganic selenium by phytoplankton and the subsequent transfer of the selenium to higher trophic levels.

AREAS SUSCEPTIBLE TO IRRIGATION-INDUCED SELENIUM CONTAMINATION OF WATER AND BIOTA IN THE WESTERN UNITED STATES
Seiler, Ralph L.; Joseph P. Skorupa; Lorri A. Peltz
U.S. Geological Survey Circular 1180, 44 p, 1999

The U.S. Department of the Interior (DOI) studied contamination induced by irrigation drainage in 26 areas of the Western United States during 1986–95. Comprehensive compilation, synthesis, and evaluation of the data resulting from these studies were initiated by DOI in 1992. Soils and ground water in irrigated areas of the West can contain high concentrations of selenium because of 1) residual selenium from the soil's parent rock beneath irrigated land, 2) selenium derived from rocks in mountains upland from irrigated land by erosion and transport along local drainages, and 3) selenium brought into the area in surface water imported for irrigation. In the Western United States, about 160,000 square miles of land, which includes about 4,100 square miles (2.6 million acres) of land irrigated for agriculture, has been identified as being susceptible. Biological data were used to evaluate the reliability of the map. In 12 of DOI's 26 study areas, concentrations of selenium measured in bird eggs were elevated sufficiently to significantly reduce hatchability of the eggs. The GIS map identifies 9 of those 12 areas. Deformed bird embryos having classic symptoms of selenium toxicosis were found in four of the study areas, and the map identifies all four as susceptible to irrigation-induced selenium contamination. The report is available at http://co.water.usgs.gov/trace/pubs/circ1180.pdf

EFFECT OF SELENITE AND SELENATE ON PLANT UPTAKE OF CADMIUM BY MAIZE (ZEA MAYS)
Shanker, K; S. Mishra; S. Srivastava
Bulletin of Environmental Contamination and Toxicology, Vol 56 No 3, p 419-424, 31 Mar 1996

Selenium has been reported to confer tolerance to toxicity of heavy metals including cadmium, a highly toxic and non essential heavy metal, which enters the food chain via plant uptake from soils. Selenium reduces availability of cadmium to plants along with other aspects of its toxicokinetics. When plants are supplied with selenite, selenium concentrations in the xylem exudate are lower than selenate. Most of the selenate was transported as selenate and unidentified organic Se compounds. In contrast, Se distribution among various Se fractions within plants does not depend significantly on whether selenite or selenate was used. Selenium has a strong tendency to form complexes with heavy metals like Cd, Hg, Ag and Tl. It has been suggested that the protective effects of selenium are due to the formation of non toxic Se-metal complexes, although the mechanism by which this protective effect is exerted remains unclear. Studies on the effect of selenium (selenite) and cadmium additions to
the soil on their concentrations in lettuce and wheat has indicated the role of selenite in reduction of cadmium uptake. The cletoxifying effect of sodium selenite on cadmium ion in the freshwater fish Potyacuthus cupanus has been reported. The discovery that an element like selenium counteracts the toxicity, chemical carcinogenesis and reduces the plant uptake of other toxic metals, highlights the possibility of existence of a Se-metal interaction mechanism in soil plant systems. The uptake and

translocation of root-absorbed chromium supplied through irrigation in the trivalent and hexavalant states in various parts of the onion plant (Allium cepa) grown in soil and sand culture has been recently reported by us. In continuation of that, this preliminary report describes the effect of selenite and selenate pretreatment on the uptake of cadmium in the maize plant (Zea mays).

MERCURY AND SELENIUM ACCUMULATION IN COMMON LOONS (GAVIA IMMER) AND COMMON MERGANSERS (MERGUS MERGANSER) FROM EASTERN CANADA
Scheuhammer, A.M; D. Bond; A.H.K. Wong
Environmental Toxicology and Chemistry, Vol 17 No 2, p 197-201, 28 Feb 1998

Liver, kidney, and breast muscle tissue from common loons and common mergansers from eastern Canada were analyzed for total Hg, organic Hg, and Se concentrations. In both species, Hg and Se concentrations were generally highest in liver, followed by kidney, then breast muscle. As total Hg concentrations increased in liver and kidney tissues, the fraction that was methylmercury (MeHg) decreased. Livers and kidneys with the highest total Hg concentrations had only 5 to 7% of the total as MeHg. Concentrations of MeHg were < 10 μg/g (dry weight) regardless of the total Hg concentration in liver and kidney. In contrast, the proportion of MeHg in breast muscle remained high in both loons and mergansers regardless of total Hg concentration, which ranged from 0.7 to 35 μg/g (dry weight). Strong positive correlations were observed between total Hg and Se concentrations, but not between MeHg and Se, in kidney and liver tissues for both loons and mergansers. Mercury concentrations were significantly higher in all three tissues of loons found in an emaciated condition compares with apparently healthy loons. Non-emaciated loons had Hg concentrations comparable to those of healthy mergansers, and concentrations were lower than those associated with Hg toxicity in birds. The elevated Hg concentrations in emaciated loons may have contributed to their impaired conditions; alternatively, the wasting of their muscle and other tissues may have caused apparent tissue Hg concentrations to increase. In any case, total Hg concentrations in liver and/or kidney tissue are
insufficient criteria for making toxicologically relevant judgments of possible Hg toxicity. Because of the varying degrees of apparent Hg demethylation in liver, kidney, and other tissues and the association of the resulting inorganic Hg with Se in an apparently stable, toxicologically inert complex, estimates of organic Hg and Se concentrations, in addition to total Hg, in these organs are recommended.

COMPARATIVE ECOTOXICOLOGY OF SELENIUM FOR BREEDING STILTS AND AVOCETS EXPOSED TO IRRIGATION DRAIN WATER
Skorupa, J.P.; H.M. Ohlendorf; R.L. Hothem; D.L. Roster; R.G. Stein; W.L. Hohman; D.Welsh; C.M. Marn; S.J. Detwiler; J. Winkel; P. Ramirez; J.A. Armstrong; P.J. Leonard
Proceedings of the Wildlife Society, Western Section, February 1993, Monterey, CA

EFFECTS OF BORON AND SELENIUM ON MALLARD REPRODUCTION AND DUCKLING GROWTH AND SURVIVAL
Stanley, T.R. Jr; G.J. Smith; D.J. Hoffman; G.H. Heinz; R. Rosscoe
Environmental Toxicology and Chemistry, Vol 15 No 7, p 1124-1132, 31 Jul 1996

Boron (B) and selenium (Se) sometimes occur together in high concentrations in the environment and can accumulate in plants and invertebrates consumed by waterfowl. One hundred twenty-six pairs of breeding mallards (Anas platyrhynchos) were fed diets supplemented with B (as boric acid) at 0, 450, or 900 ppm, in combination with Se (as seleno-DL-methionine) at 0, 3.5, or 7 ppm, in a replicated factorial

experiment. Ducklings produced received the same treatment combination as their parents. Boron and Se accumulated in adult liver, egg, and duckling liver. In adults, B and Se caused weight loss, and B decreased hemoglobin concentration, egg weight, and egg fertility. Both B and Se reduced hatching success and duckling weight, and B reduced duckling growth and duckling production, and caused several alterations in duckling liver biochemistry. Duckling survival was not reduced by B or Se, and neither B nor Se had histopathologic effects on adult or duckling liver, kidney, or spleen. There was little evidence of interaction between B and Se. This study demonstrated that B and Se, in the chemical forms and at the dietary levels administered in this study, can adversely affect mallard reproduction and duckling growth.

MERCURY AND SELENIUM IN HARBOR PORPOISE (PHOCOENA PHOCOENA) IN NORWEGIAN WATERS

Teigen, S.W.; J.U. Skaare; G. Sand; A. Bjorge; E. Degre

Environmental Toxicology and Chemistry, Vol 127, p 1251-1259, 31 Jul 1993

Concentrations of mercury and selenium have been determined in liver and kidney of 92 harbor porpoises (Phocoena phocoena) caught along the Norwegian coast. The hepatic and renal mercury concentrations ranged from 0.26 to 9.9 and 0.15 to 3.5 μg g-1, respectively, whereas the corresponding selenium concentrations ranged from 0.74 to 14.2 and 0.60 to 8.6 μg g-1, respectively. No significant differences in mean concentrations of mercury and selenium were found between females and males within the same age classes. However, the concentrations were positively correlated with age. The present results revealed a decreasing mercury concentration gradient from south to north along the Norwegian coast. In all age classes, a significant, positive correlation between the concentrations of mercury and selenium was found in both liver and kidney, the molar mercury-to-selenium ratio being 0.9660 and 0.2151, respectively. Implications of these findings for the biochemical and toxicological behavior of mercury and selenium in the harbor porpoise are considered.

SELENIUM BIOACCUMULATION BY THE WATER BOATMAN TRICHOCORIXA RETICULATA (GUERIN-MENEVILLE)

Thomas, B.V.; A.W. Knight; K.J. Maier

Archives of Environmental Contamination and Toxicology, Vol 36 No 3, p 295-300, 01 Apr 1999

The input of selenium from subsurface agricultural drainage into surface water systems can result in the accumulation of toxic concentrations of selenium in aquatic food chains. Elevated selenium concentrations in aquatic systems is a significant environmental problem in many areas of the United States. A laboratory investigation was conducted to determine the dominant route of selenium bioaccumulation by the corixid Trichocorixa reticulata, an important food chain organism. The roles of waterborne and foodborne exposure in selenium bioaccumulation were examined using 48-h bioassays. Waterborne selenium concentrations ranged from 0 to 1,000 mg Se/L as selenate. A mixture of two species of blue-green algae cultured in media with selenium concentrations ranging from 0 to 1,000 mg Se/L as selenate was used as a corixid diet in the foodborne treatments. Corixids exposed to waterborne selenate did not accumulate selenium above control concentrations. Corixids fed algae exposed to ≥100 mg Se/L as selenate had significantly higher selenium concentrations than control organisms. These data suggest that corixids may be effectively isolated from the water and selenium accumulation is solely through dietary exposure.

SELENIUM SEDIMENT TOXICITY THRESHOLDS AND DERIVATION OF WATER QUALITY

CRITERIA FOR FRESHWATER BIOTA OF WESTERN STREAMS
Van Derveer, W.D.; S.P. Canton
Environmental Toxicology and Chemistry, Vol 166, p 1260-1268, 30 Jun 1997

Waterborne and sediment selenium (Se) data, in conjunction with selected physicochemical parameters, were collected from streams of the middle Arkansas River basin, Colorado, USA, to examine the factors affecting sediment Se accumulation in a lotic environment. An empirical model of dissolved-to-sediment Se transfer in western streams, as an interactive function of sediment organic carbon content, was developed and validated. Sediment Se and associated biological effects data were compiled from the literature, to provide an estimate of sediment Se concentration thresholds that have biological effects. Based on this preliminary analysis, sediment Se concentrations of 2.5 μg/g would be a threshold based on predicted effects and concentrations of 4.0 μg/g would be the observed threshold for dish and wildlife toxicity. The dissolved-to-sediment Se transfer model can be used to translate this type of sediment Se toxicity threshold to a site-specific chronic water-quality standard for western streams based on empirically derived sediment total organic carbon values.

SELENIUM CONCENTRATIONS IN THE RAZORBACK SUCKER (XYRAUCHEN TEXANUS): SUBSTITUTION OF NON-LETHAL MUSCLE PLUGS FOR MUSCLE TISSUE IN CONTAMINANT ASSESSMENT
Waddell, B.; T. May
Archives of environmental contamination and toxicology, Vol 28 No 3, p 321-326, Apr 1995

PROTECTIVE EFFECTS OF SELENIUM ON CADMIUM TOXICITY IN RATS: ROLE OF ALTERED TOXICOKINETICS AND METALLOTHIONEIN
Wahba, Z.Z.; T.P. Coogan; S.W. Rhodes; M.P. Waalkes
Journal of Toxicology and Environmental Health, Vol 382, p 171-182, 28 Feb 1993

Selenium prevents the toxicity of the carcinogenic metal cadmium through undefined mechanisms. In this study, the authors determined the effects of selenium on cadmium toxicokinetics and on the ability of cadmium to induce metallothionein, a metal-binding protein that is thought to confer tolerance to cadmium toxicity. To assess the acute protective effects of selenium, male Wistar (WF/NCr) rats were given selenium (as SeO2; 10 μmol/kg, sc) at -24, 0, and +24 h relative to cadmium (as CdCl2; 45μmol/kg, sc). Over a 14-d period this dose of cadmium killed 6 out of 10 rats, while 100% of the cadmium-treated rats given concurrent selenium treatments survived. The acute increases in testicular weight that were seen with cadmium, indicative of edematous damage, were also prevented by concurrent selenium treatments. Further studies assessed the distribution and excretion of
cadmium and its ability to induce metallothionein in rats given 40 μmol Cd/kg, sc, at time 0 and selenium (10 μmol/kg, sc) at -24 and 0 h. Selenium treatments enhanced cadmium accumulation at 24 h in the liver (23%), testes (145%), and epididymis (35%) but reduced renal accumulation by more than half. Urine samples, collected at 0-3, 3- 6, and 6-24 h following cadmium administration, indicted a markedly reduced excretion of cadmium in selenium treated rats during all time periods. The synthesis of metallothionein was stimulated to a much lesser extent by cadmium in selenium-treated rat
kidney (41% decrease) but was unaffected in liver. The levels of cadmium-binding proteins within the testes were markedly reduced by cadmium treatment, an effect unmodified by selenium treatments. These results suggest selenium prevents acute cadmium toxicity through a mechanism that does not involve induction of metallothionein and in spite of a markedly enhanced retention of cadmium.

CONTAMINANT LEVELS IN WATERFOWL ON NATIONAL WILDLIFE REFUGES IN NORTH DAKOTA

Welsh, Daniel; Michael M. Olson, U.S. Fish and Wildlife Service, Bismarck, ND

Prairie Ecosystems: Wetland Ecology, Management and Restoration, 9-13 August 1993, Jamestown, North Dakota

In 1986, the U.S. Fish and Wildlife Service (Service) began a nationwide effort to determine baseline concentrations of potential environmental contaminants in fish, wildlife, and their habitats on National Wildlife Refuges. The impetus for this program was the discovery of severe selenium-induced reproductive impairment of aquatic birds at Kesterson National Wildlife Refuge in California. Selenium, mercury, and other toxic elements were the focus of contaminants studies on Service lands in North Dakota. Livers from American coots (Fulica americana) (n = 263) and ducks (n = 160) were analyzed for selenium, mercury, and other elements. Specimens were mainly flightless juveniles; therefore, they were representative of conditions at collection sites. Median concentrations (and interquartile ranges) of selenium and mercury in livers of American coots were 2.7 (1.8 to 4.0) and 0.67 (0.40 to 1.30) µg/g dry-weight, respectively. Median concentrations (and interquartile ranges) of selenium and mercury in livers of dabbling ducks were 5.7 (3.6 to 11.0) and 0.48 (0.30 to 1.05) µg/g dry-weight, respectively. The proceedings are available at http://www.npwrc.usgs.gov/resource/1998/wetsympo/wetsympo.htm

ACCUMULATION OF SELENO-AMINO ACIDS IN LEGUME AND GRASS PLANT SPECIES GROWN IN SELENIUM-LADEN SOILS

Wu, L; X. Guo; G.S. Banuelos

Environmental Toxicology and Chemistry, Vol 16 No 3, p 491-497, 31 Mar 1997

Seleno-amino acid accumulation was studied for two legume and two grass species grown in Selenium (Se)-laden soils. An antagonistic relationship was found between the tissue Se-amino acid concentration and the corresponding sulfur-amino acid concentration. This relationship demonstrates a competitive interaction between Se and sulfate at the amino acid synthesis level. The nonsulfur-containing amino acids were not substantially affected by the increase of tissue Se concentration. Sour clover (Melilotus indica L.) was able to accumulate much greater tissue Se concentration than the other three species. Tissue methionine concentration of sour clover, rabbitfoot grass (Polypogon monspeliensis L.), and tall fescue (Festuca arundinacea Schreb.) was not significantly affected by the increase of tissue selenomethionine concentration, but a highly significant negative correlation was found in alfalfa (Medicago sativa L.). This discrepancy suggests that a less antagonistic effect on sulfur-amino acids under the increase of Se-amino acid analogues in the tissue might be able to minimize Se toxicity to the plant. Both Se-methylselenocysteine (nonprotein amino acid) and selenomethionine (protein amino acid) accumulated in the plants when grown in Se-laden soils. Possible effects of these Se-amino acids accumulated by plants on animal health should be tested before the plants are used for forage supplementation.

SELENIUM ACCUMULATION IN CAPTIVE AMERICAN KESTRELS (FALCO SPARVERIUS) FED SELENOMETHIONINE AND NATURALLY INCORPORATED SELENIUM

Yamamoto, J.T; B.W. Wilson; G.M. Santolo

Environmental Toxicology and Chemistry, Vol 17 No 12, p 2492-2497, 31 Dec 1998

Male-female pairs of kestrels were maintained for 11 weeks on diets containing 5 or 9 ppm selenium (Se) (dry weight) as seleno-L-methionine, or naturally incorporated Se in the form of mammals collected at Kesterson Reservoir, CA, USA. Selenium concentrations in blood and excreta of male and

female kestrels within groups were similar. Near-maximal mean Se concentrations in blood were observed after the 5th week of treatment in the seleno-L-methionine-treated kestrels, and an approximately 1:1 ratio was observed between maximal blood concentrations and dietary concentrations. All treatment groups exhibited reduction of Se concentration in excreta, but not in blood, to baseline values 4 weeks after treatment ended. No birds were observed to exhibit signs of general illness or Se toxicity during the study.