Species Effects

It is generally accepted that numerous fish, invertebrate, and algal species found in the Delta have declined in abundance over the past 20 years (). These declines have been attributed to a number of causes, including reduced outflows, increased diversions, and introduced species, which, in turn, have led to lower overall productivity in the Delta. However, very little work has been done on species found in the Delta with respect to the potential effects of toxic substances. Studies that pertain to species of interest are described below.

Neomysis mercedis: Bailey (1993) evaluated the acute and chronic toxicity of the rice hervicides molinate and thiobencarb to *N. mercedis.* The data indicated that the two herbicides were additive in toxicity. Furthermore, comparison of measured concentrations of these pesticides in the Delta in 1985 with chronic toxicity values suggested that these pesticides may have reached toxic levels. Increased on-field holding times reduced concentrations of these two pesticides in subsequent years. However, in preceeding years, it is likely that concentrations were even higher than in 1985. Although no analytical data are available for the Delta for the years prior to 1985, the known application levels, shorter on-field holding times, lower river flows, and higher measured concentrations in Colusa Basin Drain, all would have contributed to higher concentrations in the Delta. As an example, Bailey (1993) calculated that concentrations in excess of 5 chronic TUs may have been reached in the Delta during the 1982 rice season.

Bailey et al. (1994) evaluated the toxicity of samples from Colusa Basin Drain, a source of agricultural discharges that enters the Sacramento River at Knight's Landing and can account for over 30 percent of the flow of the river. Ten of the 14 samples collected from CBD during rice season in 1989 produced complete mortality within 24 hr. Follow-up testing in 1990 indicated that the primary cause of toxicity was the organophosphorous pesticide methyl parathion (Finlayson et al. 1993). Reduced toxicity was observed in 1991 and was attributed to increased on-field holding times for this pesticide (Bailey et al. 1994b). In a Hazard Assessment on methyl parathion prepared by CDF&G, Menconi and Harrington (1992) pointed out that cladocerans and mysids, two important components of the Delta food chain, were among

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the most sensitive species to this pesticide. They also pointed out that, based on measured concentrations in CBD and flows in the Sacramento River, concentrations of this pesticide could have exceeded the current water quality guidelines in the Delta in the early 1980s before stricter regulations were enforced. Their calculations show that nearly 1 μg/L methyl parathion could have been present in the Sacramento River downstream of Sacramento for up to four weeks. This value is five times higher than the 96-hr LC50 for N. mercedis. In 1988, analytical measurements made in the Sacramento River near Sacramento, showed that concentrations as high as 0.32 μg/L existed; this value exceeds the LC50 for *N. mercedis* by a factor of 1.5.

Testing of individual pesticides, including carbofuran, diazinon, and chlorpyrifos resulted in the following values (Bailey et al. in prep., Brandt et al. 1992):

Pesticide	96-hr LC50 (μg/L)	NOEC (μg/L)
carbofuran	2.7-4.7	na
chlorpyrifos	0.07-0.09	0.04-0.05
diazinon	1.2-1.9	0.61-0.66

Monitoring data from different sites in the Delta suggests that these values are exceeded periodically, with the frequency depending on the pesticide. For example, Foe and Sheipline (1993) reported diazinon values in 26 samples collected from the Delta in January and February 1992. Concentrations in seven of the samples exceeded the LC50 for *N. mercedis* and 12 of the samples exceeded the acute NOEC.

Striped Bass (to be added)

Common carp

— BASE VALUE / STANDARD

Saiki and Schmitt (1986) (in #44) reported total DDT residues in samples from carp collected from the San Joaquin River that exceeded the National Academy of Sciences recommended safe level for the protection of fish-eating wildlife. These same samples exceeded the EPA estimated safe tissue concentration by factors of 8.7-14.7. Toxaphene tissue residues as high as 3.1

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mg/kg were also reported. This tissue level exceeded the threshold for adverse effects by a factor of 6 (Eisler and Jacknow 1985) (in # 44).

Alam and Maughan (1993)#66 evaluated the acute toxicity of diazinon and malathion to juvenile carp. The 96-hr LC50s for diazinon were 3.43 and 4.97 mg/L. For malathion, values of 10.21 and 10.38 mg/L were obtained.

WHAT DOES THIS MEAN ?

Kaur et al. (1993)#65 evaluated the effect of industrial effluents on the viability of carp eggs. Effluents from tannery, vegetable oil productiion, fertilizer production, and paper mill were evaluated. No-observable effect concentrations were 0.0001, 0.0001, 0.01 and 0.1 percent effluent, respectively.

Reddy et al. (1992) #67 evaluated the effect of fenvalerate, a pyrethroid insecticide, on the survival and AChE system of carp. The 48 hr LC50 was 30 μg/L. At 10 μg/L AChE was depressed and ACh increased relative to the controls. Of the tissues examined, the effect was greatest in the brain. The fish also exhibited sublethal effects and behavioral changes. Reddy et al. (1991) #75 reported that 10 μg/L fenvalerate also inhibited Mg- and Na-KATPases in the gill, brain, liver and muscle tissues. For Mg-ATPase, the liver showed the greatest effect, followed by the muscle, brain and gill. Conversely, Na-KATPase was most affected in the gill, followed by the brain, muscle, and liver. Effects were noted with exposure periods as short as 6 hr (the shortest period tested) and increased in magnitude as the exposure durations were increased to 48 hr.

Neskovic et al. (1993) #74 examined the acute and subacute toxicity of atrazine, a triazine herbicide, to carp. The 96-hr acute LC50 was 18.8 mg/L. Significant changes in the activities of the enzymes alkaline phosphatase (serum, heart, liver, and kidney) and glutamic-pyruvic transaminase (liver and kidney) were found at 1.5 mg/L, the lowest concentration tested, after 14 days of exposure. Some small changes in gill histology were also noted at this concentration.

van der Weidin et al. (1992) #76 evaluated the effect of sediment contaminated with (polychlorodibenzo-p-dioxins (PCDDs), polychlorodibenzofurans (PCDFs) and polychlorobiphenyls (PCBs) on 7-ethoxyresorufin O-deethylase (EROD) activity and cytochrome P4501A content in carp. All parameters were elevated following a 12-week exposure. This study concluded that immunoassays were useful for measuring the induction of P4501A.

Blevins (1991) #93 compared the response of the *Salmonella* assay using liver microsomal enzyme preparations prepared from carp collected from polluted and unpolluted habitats. When incubated with 2-aminofluorene, the number of revertants increased in relation to the degree of pollution the carp were exposed to. The data suggest that this assay may be useful for screening for polluted environments, particularly those contaminated with mutagenic or carcinogenic chemicals.

Double-Crested Cormorants (*Phalacrocorax auritus*)

Jones et al. (1994) #78 evaluated the bioamagnification of PCBs and TCDD-equivalents in eggs and chicks of the double-crested cormorant at different sites in the Great Lakes. Toxic concentrations of these materials results in induction of mixed function oxidases, depletion of hepatic retinoids and vitamin A, porphyria, edema and wasting syndrome. Similar effects were also seen in salmonid fishes and mink in the Great Lakes. The biomagnification factor from forage fish to cormorant eggs was 31.3. Concentrations in the chicks decreased immediately following hatching, then increased in proportion to the mass of fish consumed. Once the chicks initiated thermoregulation, the rate of accumulation increased. Weathering actually increased the proportion of more toxic PCB congeners compared with the original Arachlor mixture. Concentrations in chicks were more closely associated with local conditions than concentrations in eggs; adults tended to mix and forage widely when not feeding young. Foraging for young usually occurred relatively close to the nesting site.

Clams

Pereira et al. 1992 (#45) reported on bioaccumulation of hydrocarbons in *Potamocorbula amurensis* in Suisun Bay. Bioaccumulation of sediment hydrocarbons originating from petroleum sources was identified as was accumulation of polycyclic aromatic hydrocarbons

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derived from combustion. This species is a food source for a number of species including sturgeon and diving ducks.

Luoma et al. (1990)(#52) evaluated temporal variation in trace metals in *Corbicula* in Suisun Bay and near the mouth of the San Joaquin River over a three year period. The authors concluded that there was little chronic contamination associated with Ag, Zn, or Pb, but that substantial chronic contamination was present in Suisun Bay with respect to Cu, Cd, and Cr. Inputs of Cr were dominated by discharges from a local steel mill, and Cu appeared to originate primarily from the Sacramento River during high inflows to the Bay. Sources of Cd were attributed to both riverine and local sources. The condition factor of clams in areas with highest contamination was reduced as was the abundance of larger clams. The data suggested that the bioavailability of Cu and Cd to the clams was greater in Suisun Bay than reported in other estuaries. In fact, tissue concentrations of Cu from Suisun Bay were 6-10 times greater than reported in unenriched systems and tissue concentrations of Cd were found that exceeded levels reported anywhere in the literature. Some of the Cd tissue concentrations exceeded guidelines for human health consumption. Cr concentrations equal to the highest literature values found were also encountered.

Leland and Scudder (1990)(#53) looked at tissue metals concentrations in *Corbicula* in the San Joaquin River. Selenium concentrations varied directly with soluble Se in riverwater. Se entered the system through subsurface drain and irrigation tailwaters. Elevated concentrations of Hg, As, Cu, Cd and Ni were also found, although the concentrations varied with respect to location and source. Boron and molybdenum were not accumulated and Cr, Pb, Ag, V, and Zn exhibited little geographic variability in tissue concentrations. The authors concluded that there was no evidence of synergism or antagonism between As, Cd, Cu, Hg, Ni, and Se with respect to their uptake. Based on their data, the authors found that available Cd, Cu, and Ni were not enriched compared with other sites. Hg was elevated in the tributries and one site in the lower San Joaquin River, and Se was elevated primarily in the southern San Joaquin River and in tributaries that drained the western side of the Valley. Arsenic was enriched in the San Joaquin river and tributaries. Johns et al (1988) in #53 reported Se concentrations in the western Delta and Suisun Bay were elevated compared with sites in the southern Delta and lower

Sacramento River. These were attributed to industrial discharges (nine of the largest point source discharges release directly into Suisun Bay Gunther et al in #52). >The major impact of the San Joaquin River (aside from productivity, nursery area etc.) occurs in spring when discharge is high and export pumps not exporting.<

Chinook Salmon

96-hr LC50 for ammonia was reported to be 0.45 mg/L (unionized). The LC50 for suspended sediment was 31 g/L. Joint toxicity between ammonia and sediment toxicity was slightly less than additive (Servizi and Gordon 1990). >Check levels of suspended sediment in Bay.< SLIM

Mink and Otter

Mink have been widely used in toxicology as a model species for drug and metabolism studies (Calabrese et al. 1992 #56, Bursian et al. 1992 #55). They are also widely distributed throughout the Delta where they are one of the top mammalian predators. Consequently, they should reflect contamination frequently associated with a position near the top of the food chain. Calabrese et al (1990) reported that mink are highly sensitive to PCBs. These authors noted that mink were not particularly sensitive to chlorinated hydrocarbon insecticides but that adverse effects on growth and reproduction were found when mink were fed PCB-contaminated fish from the Great Lakes. Methyl mercury in fish also caused neurological toxicity and dioxin induced wasting syndrome and gastric lesions. Aulerich et al 199? #58 reported that diet containing > 12.5 mg/kg heptachlor given for 28 days resulted in adverse effects, particularly on growth. This level of sensitivity was considerably greater than for rodents given dietary heptachlor. Consideration should be given to a monitoring program that looks at body burdens in mink to evaluate the potential for adverse effects due to accumulation of xenobiotics.

Ropek and Neely (1993) #21 reported Hg concentrations elevated (3-4X) in otters compared to the concentrations in their diet. Hg was accumulated in both liver and kidney (higher in liver). Males accumulated more than did females. Average levels were 2.2 mg/Kg in liver (dry wt.) and 1.5 mg/Kg in kidney. Daily dietary levels of 2 ppm methylmercury were lethal within 7 months (O'Connor and Nielsen 1981 in #21). Liver levels in otter from polluted areas

(Georgia) averaged 7.5 ppm.

Bald Eagle

Bald eagles occupy high trophic levels and so may be contaminated by xenobiotics that accumulate in the food chain to harmfuls levels. They may also be adversely affected by ingesting lead fragments in dead or wounded waterfowl (Langelier et al 1991 #61 and Gill and Langelier 1994#60) or by accidental pesticide poisoning (Bowes et al 1992 #62, Colburn 1991 #63). Pesticides associated with eagle mortalities include dieldrin, endrin, , DDE, DDT and carbofuran. The birds are present in the system seasonally and could be affected by lead-contaminated waterfowl during hunting season, although there is little local information on this. Data from bald eagle populations in the Great Lakes suggests that accumulation of toxic chemicals through the food chain has effectively reduced succesful reproduction in several populations. The chemicals of major concern include DDT, DDE and PCBs, dioxins and furans (Colburn 1991 #63). The problem is exacerbated because the eagles not only feed on contaminated fish but also on birds that feed on the fish, thus effectively increasing the biomagnification. Other birds feeding on the same types of feed also are experiencing reproductive falilures, including Caspian, Foster's and common terns, osprey, double-crested cormorant, and herring gull. Since the eagles are transient to the area, looking at some of these fish-eating birds that are residents would be appropriate. Mink and otter were also indicated as species showing reproductive failure and population declines consistent with the eagle.

Grubb et al (1990) #20 reviewed the relationship between eggshell thinning and contaminant levels in bald eagles in Arizona. Eggshells were thinner than from pre-DDT era, but productivity was improving. All eggs analyzed included detectable levels of Hg, DDE and PCBs. Hg was below levels known to cause effects. Concentrations of contaminants (DDE and PCBs) decreased in eggs between 1977 and 1982. Overall, DDE levels of 1-2 ppm wet weight in eggs did not appear to affect reproductive success as did PCB levels of 0.4-0.9 ppm. Local populations varied appreciably in their tissue concentrations.

Anthony et al (1993) #24 described environmental contaminants in Bald eagles in the Columbia river estuary. High levels of DDE, PCBs and TCDD were found in eggs and adults. DDE and PCBs were also found in nestlings indicating early dietary exposure. Hg levels were higher in adults, indicating accumulation with age. The role of dioxin was unclear but concentrations in eggs were similar to those found to have deleterious effects in other species in laboratory exposures. Resuspension of dredged river sediments played an important role in bioavailability. Eggshell thinning was present and related to DDE and PCBs. DDE and PCB concentrations averaged 9.7 and 12.7 ppm (wet weight) respectively. TCDD concentrations averaged 60 ppt in eggs. Contaminant levels were 2-3X higher in northern squawfish than in suckers, both components of eagles' diets. Fish-eating birds were probably the source of DDE but fish were more likely source of PCBs (tissue concentrations of PCBs in all fish samples exceeded 0.5 ppm-the recommended level for protection of fish-eating birds and mammals). Three of 12 fish samples contained Hg concentrations that exceeded dietary levels shown to interfere with successful reproduction in mallards. Kubiak et al in #24 concluded that PCBs were responsible for embryotoxicity in Foster's tern in Lake Michigan. The TCDD residues in eagle eggs (60 ppt) were higher than concentrations (37 ppt) found to impair reproduction in Foster's terns in Lake Michigan. TCDD levels in prey species averaged 2.8 ppt, 40X higher than fish consumption guideline for human health (EPA). Elevated concentrations of DDE and PCBs were also found in mink, otter, and black-crowned night herons. A link between fish uptake and dredging of PCBs and DDE has been demonstrated (Seelye in #24).

Frenzel and Anthony (1989) #25 found that exposure to environmental contaminants in wintering bald eagles was greatly dependent on the exposure history of the prey item. In many cases, exposure to embedded lead shot in waterfowl constituted the greatest hazard. Organochlorines were and Hg were low in voles and jackrabbits. Waterfowl had higher levels, with dabbling ducks < diving ducks < western grebes and California gulls. Dietary exposures of wintering and nesting and rearing eagles may differ greatly.

Wiemeyer et al (1993) #30 reviewed the effect of environmental contaminants on bald eagle productivity. Young production was normal if the eggs contained < 3.6 μg DDE/g, reduced by half between 3.6 and 6.3 μg/g and by half again at > 6.3 μg/g. Other contaminants were also associated with poor reproduction but, since they were highly correlated with DDE, it was difficult to assess their individual effects. Concentrations of contaminants appeared to be declining in many parts of country between mid-70s and mid-80s, but specific contaminant(s) varied with location. The data support the concept of a threshold effect for DDE. The effect of PCBs is uncertain, there are very toxic coplanar congeners that we know relatively little about.

Craig et al. (1990) #36 evaluated lead toxicity in golden and bald eagles. Liver concentrations of ≤ 2 ppm were indicative of uncontaminated birds, 2-8 ppm, sublethally contaminated, and ≥ 8 ppm acutely contaminated. Uptake of lead was probably not from organisms contaminated from feeding at a lead-contaminated site, but from hunter-killed game, including waterfowl.

Mosquitofish

Lee et al. (1992) #72 evaluated the effect of acute inorganic mercury exposure on populations of mosquitofish. There was a maternal effect in that groups of fish that shared a common mother exhibited similar sensitivities to Hg. This implies a heritable genetic component to sensitivity.

Chagnon and Guttman (1989) #90 evaluated the effect of copper and cadmium on the survival of populations of mosquitofish containing different allozyme genotypes. For both metals, differences in survival were associated with different genotypes. The authors noted that correlations between heavy metal stress and allelic and genotypic frequencies at the phosphoglucomutase (PGM) and/or the glucose phosphate isomerase (GPI) loci have been generally noted in marine and freshwater invertebrates and fish. Strittholt et al. (in #90) suggested that the current lack of allozyme variability in yellow perch in Lake Erie was due to selection from heavy metal pollution.

Heagler et al. (1993) #91 also investigated the effect of mercury exposure on allozyme genotypes in mosquitofish. One of the nine loci investigated, GPI, was correlated with time to death in the laboratory study. A follow-up investigation compared fish from Hg-contaminated and control sites. The fish from the contaminated site exhibited significantly lower frequency of one of the GPI alleles than did fish from the uncontaminated site.

In follow-up work, Kramer and Newman (1994) #92 compared the effect of Hg on the gluconeogenic properties of preparations of two different GPI allozymes. The results suggested that the allozyme generally associated with increased sensitivity to Hg (and As), *Gpi-2*$^{38/38}$, was not differentially inhibited by Hg, suggesting that the associated allele is a marker closely related to a gene(s) that confer susceptibility to Hg toxicity.

Crayfish

Holck and Meek (1987) in #79 reported the LC50 of the crayfish *Procambarus clarkii* exposed to the pyrethroid insecticide resmethrin to be 0.82 μg/L.

WHAT DOES THIS MEAN?

Tadpole Shrimp (*Triops longicaudatus*)

Walton et al. (1990) #79 evaluated the toxicity of four pesticides to tadpole shrimp. The following 24-hr LC50s (in μg/L) were obtained : 4.0 (chlorpyrifos); 73.8 (fenthion); 0.084 (cypermethrin); and 0.7 (resmethrin). In field studies, the lowest effective concentrations were (in g/ha): 11 (chlorpyrifos -EC 4); < 56 (fenthion-EC 4); 1-3 (cypermethrin -EC 2.5); and < 28 (resmethrin-18%).

Blackbirds

Meyers et al. (1992) #80 evaluated the toxicity of chlorpyrifos and dimethoate to red-wing blackbirds *Agelaius phoeniceus* and starlings *Sturnus vulgaris*. For dimethoate, the reported LC50 values for adult starlings and blackbirds were 32 and 6.6 mg/kg, respectively. For chlorpyrifos, the values were 5.0 and 13.0 mg/kg, respectively. Nestlings responded differently. A single dose (oral) of 2 mg/Kg chlorpyrifos reduced the survival of blackbird nestlings by approximately 50 percent over a 10 day period, but did not affect survival of starling nestlings. In contrast, a single dose of 50 mg/kg dimethoate did not affect the survival of blackbird nestlings, but did reduce the survival of starling nestilings by 56 percent. Growth was not affected in birds that survived exposure.

Catfishes

Lin et al. 1994 #81 looked for metabolites of polycyclic aromatic hydrocarbons (PAHs) in the bile of brown bullhead *Ameiurus nebulosus* collected from four tributaries to Lake Erie. Concentrations of PAH metabolites in the bile of fish from sites with contaminated sediments were 5-20 times greater than those from sites with uncontaminated sediments.

Murdoch and Hebert (1994) measured mitochondrial DNA diversity in brown bullhead from sites in the Great Lakes having sediments contaminated with heavy metals, PAHs, PCBs, chlorinated pesticides and petroleum hydrocarbons. Their results demonstrated considerable differences in mDNA between sites, with a consistent reduction in haplotype diversity at contaminated sites compared with fish sampled at reference sites. The authors concuded that the decreased diversity was associated with population bottlenecks, in this case severe selection associated with environmental degradation, i.e., pollution. They also pointed out the advantages of brown bullheads for this type of research; they are sensitive to contaminants frequently found in dediments and tend to be representative of local conditions because they do not undergo extensive migrations.

Steward et al. (1990) #86 investigated the metabolic fate of benzo[a]pyrene in brown bullhead. Most of the BP was found in the bile, liver, and gut, with significant quantities also associated with the spleen, gonads and muscle. The hepato-biliary system was the major route of excretion. Metabolism produced the highly genotoxic BP-7,8-diol and other bioactive metabolites. The presence of the parent compound and active intermediates in the muscle is of concern to those who consume contaminated fish.

Hasspieler et al (1994) #31 compared glutathione response against xenobiotics in channel catfish and brown bullhead. Brown bullhead mounted less of a response and maintained lower levels of hepatic total glutathione and reduced glutathione than channel catfish. This is consistent with brown bullhead expression of neoplasms in contaminated systems compared with channel catfish which rarely express pollutant mediated neoplasia. Thus brown bullhead would appear to be more sensitive to GSH arylators and oxidants. Reduced glutathione protects against oxidants as an antioxidant defense and is a substrate for conjugation reactions.

Gallagher and Di Giulio (1989) #38 evaluated the effects of complex waste mixtures on hepatic monooxygenase activity in brown bullhead. In spite of lip and jaw lesions and liver damage, measures of MFO activity (cytochrome p450, EROD, etc.) were not good indicators of fish from the contaminated site. The authors pointed out that MFOs may respond well to specific chemicals (PAHs and PCBs) but their response to complex mixtures is not well characterized; the presence of selected metals may suppress enzyme activity.

Minnows

Dyer et al. (1993) #88 investigated the synthesis and accumulation of stress proteins in fathead minnows *Pimephales promelas* exposed to inorganic arsenic (sodium arsenite). The 96-hr LC50 was found to be 9.9 mg As/L. The stress protein response was elicited rapidly, within 2 hrs in the gill at 25 mg/L As. In the gill, synthesis of 20, 70, 72, and 74 kD proteins were significantly correlated with mortality but, in striated muscle, only the 70 kD proteins were correlated with mortality. Gill tissue produced a greater variety of proteins and a greater response at lower concentrations than did muscle tissue.

Lindstrom-Seppa et al. (1994) #41 described the uptake of 3,3',4,4'-tetrachlorobiphenyl (TCB) and induction of cytochrome P4501A in fathead minnows. High concentrations suppressed EROD activity. TCB was passed into eggs. Maintenance of CYP1A may last 2 weeks following induction. In female fishs, etradiol may suppress CYP1A induction. Endothelial cell lining was an important source of CYP1A, with greater induction than in epithelial structures.

Cnidarians

Fu et al. (1994) #89 compared the toxicities of industrial wastewaters to *Hydra attenuata* and fathead minnows. Of the 20 samples tested for acute toxicity, *Hydra* were more sensitive than fathead minnows to 16 samples (by factors of 1.1-5.5), equally sensitive to 2 samples, and less sensitive (by factors of ≤ 2.2) to two samples. The authors point out that *Hydra* were more sensitive to antimony than rainbow trout, fathead minnows, annelids, amphipods, and caddisflies.

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Muskrat

Halbrook et al. (1993) #94 compared muskrats inhabiting polluted and unpolluted sites. They found that muskrats inhabiting a contaminated waterway exhibited reduced fat indexes and spleen weights, greater adrenal weights, and increased incidence of disease and parasitism compared with those found in relatively uncontaminated sites. Increased body burdens of aluminum, cadmium, copper, nickel, zinc, and polyaromatic hydrocarbon compunds were associated with muskrats collected from the polluted site. Fish from the same waterway also exhibited signs of adverse effects including fin erosion, cataracts, and liver tumors.

Other Rodents

Ainsworth et al 1991 #19 evaluated uptake and retention of antimony in voles *Microtus agrestis* over a 60-day period. At a dietary level of 500 mg/kg, antimony was concentrated preferentially in the liver, at ≥ 3 times the levels found in kidney and lungs. Young voles also had elevated levels in liver following birth from an exposed female. Growth and survival were not affected and clearance rates appeared rapid (approximately 87 percent within 7 days). The uptake of the pregnant vole was much higher than nonpregnant voles and antimony was higher in kidney than in other organs. Others have also reported reproductive effects with antimony. Aside from diet, inhalation of particles from smelters may also be an important sources of uptake.

Sediment Toxicity

Swartz et al (1994) #23 compared sediment toxicity, contamination and amphipod abundance at a site in San Francisco Bay contaminated with DDT and dieldrin. The Lauritzen and Santa Fe Channels and part of Richmond Inner Harbor have been designated as aSuperfund Site. Property adjacent to the sites wasvused to formulate DDT and dieldrin from 1945 to 1966. In some areas, largely removed in 1990, banks along the Lauritzen Channel contained virtually 100 percent DDT. Sediment concentrations are highest in Lauritzen Channel, decreasing through the Santa Fe Channel to Richmond Inner Harbor. Sediment samples were evaluated for toxicity with

Eohaustorius estuarius, concentrations of contaminants, and abundance of amphipods in field. Except for one site in the Santa Fe Channel with high PAH levels, concentrations of PAHs, PCBs, and metals were not high enough to cause toxicity. Threshold sediment toxicity occurred at 300 μg DDT/gOC for *E. estuarius* and at 100 μg DDT/gOC for the field populations of amphipods. One species of amphipod, *Grandidierella japonica*, appeared to be tolerant of elevated DDT concentrations. Average mortalities for *E. estuarius* were 42, 30 and 24 percent in samples collected from the Lauritzen Channel, Santa Fe Channel and Richmond Inner Harbor, respectively. Only sites in the Lauritzen Channel contained sufficient DDT to account for mortalities. Pinza et al (in #23) found toxicity to *Rhepoxynius abronius* in sediment samples collected from the southeastern bank of the Richmond Inner Harbor Channel. Data from both studies suggest that contamination and associated toxicity were patchy; sites in Lauritzen Channel only meters apart produced 35 - 100 percent mortality. Similarly, samples collected from 26 sites in the South Bay produced an average 45 percent mortality in *R. abronius*, with a range of 20-100 percent mortality. Interstitial water threshold concentration of DDT was 0.5 μg/L, with 10-day LC50 of 2.2 μg/L.

Long et al. (1990) #34 evaluated toxicity of sediments from San Francisco Bay with a variety of species. Three samples were from Oakland Inner Harbor, and three each from Yerba Buena, Vallejo and San Pablo. Tests included elutriate tests with mussel *M. edulis* and sea urchins *S. purpuratus*, solid phase sediment tests with amphipods *R. abronius* and *A. abdita*, and pore water tests with the polychaete *Dinophilus gyrociliatus*. Reduced survival (≤ 45%) was seen with *R. abronius* in all three OIH samples, 1 of 3 Vallejo samples and 1 of 3 from San Pablo. The response in samples from Yerba Buena was more uniform and averaged about 65 % survival compared with 95% in controls. With *A. abdita*, only one of the OIH samples reduced survival and no effects on survival were seen in samples from the other sites. With *M. edulis*, reduced survival was seen in all of the samples from OIH, 2 of 3 from Yerba Buena, 1 of 3 from Vallejo and 1 of 3 from San Pablo. Larval abnormalities were also evaluated with this test; they were less than 25 % in all samples. With the sea urchins, there was no effect on normal development but mitotic aberrations, micronucleated cells, and cytologic abnormalities were elevated in samples from all sites compared with the controls. With the polychaete, none of the samples reduced survival, but eggs per female were reduced in 2 of 3 of the samples from OIH and in all

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of the samples from Yerba Buena. Chemical analyses indicated that PAHs, DDT, total chlorinated pesticides, and PCBs were elevated in OIH samples compared with other sites. Vallejo sites had lower PAHs than other sites. All of the Bay sites had higher levels of these contaminants than samples from Tomales Bay. Correlations with different contaminants suggested that different organisms often responded to different contaminants.

Ankley et al. (1992) #42 point out the contribution of ammonia and hydrogen sulfide to sediment toxicity.

California Black Rail

Evens et al (1991) #26 reviewed the status of the California black rail. The bulk of the population was confined to the northern marshlands of San Francisco Bay. The populations are undergoing a decline, presumably due to habitat loss or degradation. The effects of contaminants are not known, but have affected other bird species in estuary.

Inorganic Toxicants

Saiki et al (1993) evaluated boron, molybdenum and selenium in aquatic organisms in the lower San Joaquin drainage. Concentrations of boron and selenium were elevated in reaches that received tile drainage. Boron and molybdenum were not biomagnified in food chain. Selenium appeared to be biomagnified. Selenium concentrations in some areas in fish reached 23 μgSe/gm body wt. (dry weight), twice as high as needed to elicit reproductive effects. Boron levels were also somewhat elevated. Chinook salmon and striped bass fingerlings accumulated up to 200 μg/g B after 28 days of exposure to tilewater and also exhibited poor survival. Threshold Se concentrations associated with reproductive failure in fish include: 2-5 μg/L in water, 4 μg/g in sediment,5 μg/g in food and 12μg/g in whole fish. Whole fish as low as 3-8 μg/g reduced growth and survival in juvenile chinook salmon. Authors concluded that any increase in tile drainage to the San Joaquin River will further increase adverse effects on fish.

Fairy Shrimp *Branchinecta longiantenna*

Mizutani et al. (1991) evaluated the uptake of lead, cadmium and zinc by fairy shrimp. These shrimp inhabit temporary rain pools. Organisms tolerated 25 mg/L Pb for two days, but 1 mg/L Cd or Zn was lethal. At 15 mg/L Pb, 0.1 mg/L Cd or Zn, exposed organisms died within 6-8 days. *B. longiantenna* accumulated all three metals which may be a source of concern since this species can be a significant source of food for migratory birds. Also, brine shrimp *Artemia salina,* which are widely distributed in salt ponds and consumed by birds, accumulate Cd to 100 mg/kg (wet wt.) Jennings and Rainbow in #37.

To pesticides: [Gilliom and Clifton (1990) reported total DDT concentrations of 0.01-0.08 μg/L in water samples collected from the San Joaquin River at Vernalis. These values exceeded the EPA 24-hr water quality criterion by factors of 10-80. Based on sampling conducted in 1985, Gilliom and Clifton concluded that concentrations of organochlorine pesticides in bed sediments of the San Joaquin River were among the highest measured in major rivers in the United States.]

To pesticides: [Norberg-King et al. (1991) #33 conducted a TIE on toxic samples from Colusa Basin Drain. Rice is single largest use of irrigation water in Sacramento valley. Rice return flows most of drain, comprise up to 33% of Sacramento River flow, discharged along a 90 km stretch of river between Colusa and Verona at feather river. Methyl parathion and carbofuran identified as source of invert toxicity. Additive toxicity. Consider showing the spread of values for toxicity from hazard assessments; note potential to shape species assemblages. Carbofuran in natural water half life was 3 weeks (Sharom et al in #33).]

To pesticides: [Finlayson et al (1991) #35 demonstrated methyl parathion in CBD was source of toxicity to N. mercedis. Noted that cause of SB decline could be due to direct effects on SB and/or to food organisms.]

>Note estuary's susceptibility to pollution effects and flow-related hydrodynamic effects on contaminants.<

To Refinery Effluents: Chapman et al (1994) #22 evaluated the toxicity of refinery waters to a variety of aquatic organisms. There was a wide range of sensitivity observed but some species of fish and invertebrates were adversely affected at ≤ 10 percent effluent. The authors also noted eroded fins. Weiss et al (in #22) found effects on winter flounder, striped bass, and mummichog at 10 percent effluent (growth and development). With fathead minnows, DeGreave et al (in #22) found NOECs of 0.5 and 21.6 percent.

<u>To municipal effluents</u>: [Ankley et al. (1990) #40 demonstrated that surfactants may be responsible for toxicity in municipal effluents.]