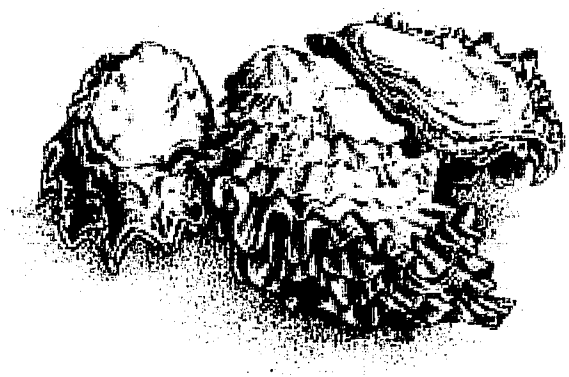
Status Report and Synopsis of Organic Pollutants in Relation to Shellfish Safety in the Mad River Slough and Humboldt Bay, California



Prepared for:

Humboldt Bay Harbor Recreation and Conservation District

Co-Sponsors:

Kuiper Mariculture, Inc.,
North Bay Shellfish, and
Humboldt Bay Oyster Co.

Prepared by:

Pacific Shellfish Institute,
Olympia, Washington

February 2007

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Executive Summary

Studies of dioxin levels in bivalve shellfish indicate in most regions of the United States and other countries, concentrations are well below levels considered by the USFDA and USEPA to be a human health risk. Most long-term studies demonstrate a decline in dioxin levels, and for a large part, industries releasing these pollutants have come under more stringent regulation. A 2002 survey of dioxins and other chemicals in shellfish from the Mad River Slough and Humboldt Bay found their levels to be the same as or marginally higher than those detected in the majority of studies at other locations. California Department of Health Services (CDHS) sampling from Humboldt Bay in 2003 indicated much lower levels, with dioxin concentrations in shellfish at or near the detection limits. Although there are no similar long-term data from Humboldt Bay shellfish to offer a historical perspective of dioxin levels, trends in recent years suggest that in the absence of continued inputs, dioxin are continuing to decrease to naturally occurring levels.

The available literature indicates there is no risk of contamination from consuming shellfish from Humboldt Bay. Dioxin concentrations in Humboldt Bay shellfish are similar to or lower than the background levels found in foods throughout the U.S. The average U.S. population is not considered high risk due to the low levels of shellfish consumption. However, attention has been given to unique populations consuming a higher than average amount of shellfish and other foods that may be high in dioxin. These populations include subsistence fisheries, Native Americans and Asian Pacific Islanders. Even with the high consumption rates of these unique populations, according to the USEPA, the only known incidence of high dioxin levels in humans has resulted from accidental exposure, not from diet.

After review of pertinent studies, reports and health criteria, it is concluded that Mad River Slough and Humboldt Bay, as a shellfish growing areas, meet all standards of safe harvest and consumption of commercially grown shellfish within the wet and dry weather standards administered by California Department of Health Services. The Humboldt Bay Harbor Recreation and Conservation District as the state tideland trustee is meeting its obligations under the trusteeship to ensure that shellfish culture activities presently permitted on leased tideland conform with human health criteria as they relate to dioxin.

Introduction

Oysters, clams, mussels and other shellfish are widely consumed and important seafood crops grown and harvested in California and elsewhere in the U.S. In 2004, over 600,000 pounds of oysters were commercially grown in Humboldt Bay, according to the California Marine Region Aquaculture Coordinator. Along with the bay's oyster and clam seed production, Humboldt Bay shellfish was valued at over $5.5 million accounting for nearly 64% of the state's $8.6 million shellfish industry. Shellfish are also credited for improving water quality and fish habitat in our coastal estuaries. One of the most characteristic aspects of bivalve shellfish, such as oysters and clams, is their extraordinary ability to sort out and retain fine particles and dissolved materials out of the water. For example, individually, oysters pump an estimated 1 ½ to 3 gallons per hour. Therefore, even a small bed of several thousand oysters can filter out and concentrate a wide variety of materials from a very large volume of water.

Because of their unique biological filtering capacity, it has long been recognized that bivalve shellfish must be closely monitored to detect concentrations of human pathogens, natural harmful algal toxins, and natural and man-made pollutants retained in their tissues which could pose a human-health risk. Public health agencies routinely monitor commercial, recreational and tribal harvest areas for the presence of a wide variety of pathogens, toxins and pollutants. In California, the Department of Health Services (DHS) is primarily responsible for the analysis of shellfish and informing the public about food safety. Shellfish growers in California also have an important role in this task, and are partially responsible for water quality and product monitoring. In addition, because many of the farms are located in coastal estuaries, such as Humboldt Bay, shellfish farmers actively pursue a variety of measures to ensure maintenance of a high quality growing environment for their products. Many of these measures are codified under the National Shellfish Sanitation Program (NSSP), which is overseen by the U.S. Food and Drug Administration (FDA). State and federal regulators work closely with the shellfish industry through the FDA Interstate Shellfish Sanitation Committee and regional shellfish organizations, such as the Pacific Coast Shellfish Growers Association the and Pacific Rim Conference. Through these organizations, shellfish consumers are assured that health considerations are given the highest priority and shellfish producers are provided with tools and guidance for assuring the safety and quality of their products. The resulting food health safety requirements for all farmed and commercially harvested shellfish is exceedingly stringent, with a level of product and environmental monitoring greatly exceeding in sophistication and intensity that of most other food crops.

New Food Safety Challenges

With increased understanding and awareness of food safety hazards, new seafood health issues have gained broad public prominence. Seafood producers have seen a significant rise in concern expressed by both the popular press and academic literature related to, for example, measured or perceived levels of mercury in swordfish and PCBs (polychlorinated biphenyls) in salmon. Shellfish are included in this discussion, with much of the regional media focused on the effects on mussels and razor clams of several new types of naturally occurring toxins associated with harmful algal blooms or HABs.

In recent years, oyster growers in Humboldt Bay have seen their products come under increased scrutiny for a group of organic compounds known informally as "dioxins" stemming, in part, from past operations of pulp and timber mills in the area. This was perceived as a potentially serious issue due to: 1) the extremely low levels of these chemicals permitted in foodstuffs; 2) the recognized ability of oysters and other bivalve shellfish to bioaccumulate the chemicals; and 3) the heightened sensitivity of the public and environmental regulators to the significance of the chemicals in the environment. In addition to organic compounds, shellfish growers have seen greater international attention focused on metals – with some product being rejected by buyers due to high but naturally occurring levels of cadmium. Fortunately, cadmium and other metals of concern have not been found in shellfish from Humboldt Bay.

This report takes a closer look at the key elements of these new food safety challenges by focusing on issues affecting the Humboldt shellfish producers. It addresses the following common areas:

- Dioxins in relation to the safety of shellfish for human consumption.
- Recent comparative peer-reviewed studies and technical reports related to dioxins contamination in shellfish.
- California state, federal and international health standards related to the safety of shellfish for human consumption, with emphasis on organic chemicals and metals.
- Studies of dioxin and other chemicals in the Mad River Slough and adjacent Humboldt Bay area and relation to human consumption of shellfish
- Relevant studies that may be underway by California Department of Fish and Game, its contractors or affiliates

A Dioxin Overview

Dioxin is a term given to hundreds of similar chlorine containing organic compounds as well as the closely related polychlorinated biphenyls (PCBs). Typically the term applies to polychlorinated dibenzofurans/dibenzo-p-dioxins (PCDF/PCDDs) and other dioxin-like substances. The term dioxin congener is often used to describe chemicals in this group. Sometimes the term dioxin is also used to refer to the most studied and one of the most toxic dioxins, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) (EPA, 2004a & b).

Dioxins are formed as a result of combustion processes such as commercial or municipal waste incineration and from burning fuels (like wood, coal or oil). There are natural sources for dioxins like brush and forest fires and volcanic eruptions, although these sources contribute very low background dioxin levels. Chlorine bleaching of pulp and paper, certain types of chemical manufacturing and processing, and other industrial processes all can create small quantities of dioxins. Cigarette smoke also contains small amounts of dioxins (EPA, 2004a & b).

Over the past decade, federal, state and local governments and industry have worked together to dramatically reduce dioxin emissions. Dioxin levels in the United States environment have been declining for the last 30 years due to reductions in manmade sources. However, because they are extremely persistent compounds, levels of dioxins still exist in the environment from both manmade and natural sources. Therefore, a large part of the current U.S. dioxin exposures is due to past release of manmade dioxins, even decades ago. If all human-generated dioxins could somehow be eliminated, low levels of naturally produced dioxins will remain (EPA, 2004a & b).

Current analytical methods allow dioxin levels to be measured in very small amounts. Dioxin concentrations are typically reported as picograms (pg), which is one trillionth of a gram (454 grams = 1 pound). Typically amounts will be shown either as pg/person/day or pg TEQ/g. TEQ is the total dioxin toxic equivalent, which is calculated by measuring the toxic equivalence factor (TEF) of each individual dioxin congener in a sample. The TEF is a value assigned to each congener by the World Health Organization (WHO). Another common format for reporting dioxin concentrations is parts per trillion (ppt), which is a unit of concentration that is equal to 1 part in 1 trillion, or 1 particle for every 999,999 other particles.

Overview of Human Health Impacts

Studies have shown that exposure to dioxins at high enough concentration s may cause a number of adverse health effects. Because dioxins from natural and anthropogenic sources have been widely distributed throughout the environment since the early 1900's (and before), almost every living creature, including humans, has been exposed to dioxins. The health effects associated with dioxins depend on a variety of factors including: the level of exposure, when someone was exposed, exposure length and frequency. Because dioxins are so widespread, we all have some level of dioxins in our bodies (EPA, 2004a & b).

The most common health effect among people exposed to large amounts of dioxin is chloracne. Such levels have typically been the result of accidents or significant contamination events. Chloracne is a severe skin disease with acne-like lesions that occur mainly on the face and upper body. Other effects of exposure to large amounts of dioxin include skin rashes, skin discoloration, excessive body hair, and possibly mild liver damage (EPA, 2004a & b).

One of the main health effects in question for dioxins is the risk of cancer in adults. Several studies suggest that workers exposed to high levels of dioxins over many years have an increased risk of cancer. Animal studies have also shown an increased risk of cancer from long-term exposure to dioxins. Finally, based on data from animal studies, there is some concern that exposure to low levels of dioxins over long periods (or high level exposures at sensitive times) might result in reproductive or developmental effects (EPA, 2004a & b).

Typical paths of human exposure

Most of the population has low-level exposure to dioxins. Although dioxin is an environmental contaminant, most dioxin exposure occurs through the diet, with over 95% coming through dietary intake of animal fats. To date FDA monitoring of dairy products and fish shows that when detectable levels are found they are generally consistent with EPA estimates for background occurrence of dioxins. The only known incidents of high dioxin levels in humans have resulted from accidental exposure; not typical dietary exposures (EPA, 2004a & b).

Dioxins in food products and human health risk

The human health risk posed by dioxins in foods varies with different populations, individual lifestyle, and historical exposure factors. For example, shellfish consumption rates differ depending on geographic location, diet, and health. Populations subsisting heavily on shellfish, such as coastal native peoples and some immigrant populations, consume more shellfish than the average population of the U.S. In addition, individual exposure levels will vary widely because dioxins are found in many other foods regularly consumed, including dairy products and beef.

Research over the last decade illustrates the complexities in dealing with potential low-level contaminants in foods. In 1994 researchers compiled a list of fish consumption advisories resulting from chemical contamination of fish and shellfish species throughout the United States. At the time, four pollutants triggered 90% of the advisories: mercury, PCBs, chlordane, and dioxin (Cunningham et al, 1994). The Food and Drug Administration (FDA) later published a survey of dairy products and commercial fish and shellfish, and reported on levels of 17 dioxin/furan cogeners.

Samples for the FDA report were collected in 1995 and 1996. Products sampled included various cheeses, ice cream, yogurt, butter, milk, canned tuna, catfish, shrimp, cod, blue crab, and oysters. The bounds on mean dioxin intakes (pg/person/day) calculated for consumers of oysters were estimated at 16.1-16.6 pg/person/day (Jensen et al, 2001).

The Washington State Department of Health recently assessed the level of contaminants in the Lower Elwha Klallam Tribal (LEKT) fishing area in Port Angeles, Washington in response to concerns over possible contamination from pulp and paper mill effluents (WDOH, 2005). Dungeness and red rock crabs and geoduck were sampled and analyzed for dioxin toxic equivalent (TEQ) concentrations. The mean and maximum TEQ concentration for each species varies, depending on how undetected dioxins and dioxin-like compounds were treated when deriving the TEQ. Assuming ½ the detection limit (DL) for chemicals not detected yields slightly higher results than assuming a value of "0" for non-detects. Results of the crab and geoduck analyses are presented in Table 1. These concentrations were then compared to other commonly eaten food. Other foods included freshwater fish and shellfish, marine fish and shellfish, beef, pork, dairy products, poultry, eggs, and milk.

Table 1. Dioxin TEQ concentrations of geoduck and crab samples taken in 2005 from the Lower Elwha Klallam Tribe fishing grounds near Port Angeles, WA. (WDOH, 2005)

Species	*N*	*Mean TEQ pg/g *(0 DL)*	*Mean TEQ pg/g (1/2 DL)*	*Max TEQ pg/g (0 DL)*	*Max TEQ pg/g (1/2 DL)*
Geoduck clam	5 (Composite	0.019	0.027	0.27	0.034
Dungeness crab	4 (Composite)	0.18	0.18	0.32	0.32
Red rock crab	7 (Composite)	0.013	0.025	0.034	0.043
* pg/g = picogram per gram or part per trillion					

Figure 1 illustrates measured levels of dioxin TEQs in commonly eaten foods and crab and geoduck. Geoduck and red rock crab from the LEKT fish area had the lowest dioxin TEQ levels of the reported foods. Whole Dungeness crabs had similar levels as other types of animal protein such as beef and pork. This indicated that limiting the diet of geoduck, Dungeness and red rock crab was not likely to decrease the level of dioxin consumed (WDOH, 2005). These observations are consistent with WDOH bivalve shellfish sampling elsewhere where organic contaminants, such as dioxin, are poorly accumulated relative to metals such as zinc and copper. This is largely due to the low fat content of bivalve shellfish verse other types of animal products.

Judd, et al (2004) used dioxin-like PCBs to assess the risk of contaminants to different consumption groups. In the Pacific Northwest and Western Canada, Asian and Pacific Islander populations and tribal nations were reported to consume ten times more fish and seafood than the average U.S. consumer. These populations' dietary practices may lead to significant exposures to persistent pollutants because regulatory evaluation of fish consumption does not always take into account the unique consumption and cooking practices of these groups.

The European and Canadian literature offers a different perspective on dioxin contamination in shellfish and seafoods. Pompa, et al. (2003) compared dioxin and other contaminant levels in food in European countries and the U.S. Consumption rates of foods in different countries, and the intake of dioxins based on these consumption rates were also assessed. Dioxin levels were about 10 times higher in fish and shellfish than other animal products. Consumption data were compared to Total Daily Intake (TDI) guidelines from several different sources, including the World Health Organization (WHO) and the European Commission, Health and Consumer Protection Scientific Committee on Food (SCF). It was determined that high level consumers, in the 95th percentile, regularly exceeded the upper limit of the TDI set by the WHO.

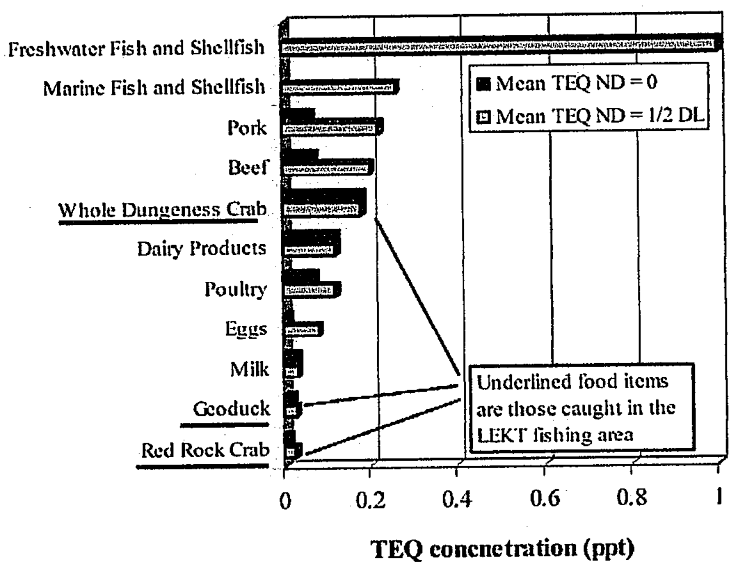

Figure 1. Measured levels of dioxin toxic equivalent TEQs (pg/g) in commonly eaten foods and crab and geoduck (from the LEKT fisheries area).

In the 1980s several shellfish harvest areas near pulp and paper mills in British Columbia, Canada, were closed to harvest due to elevated levels of dioxin. These closure areas have been progressively reopened since 1995 in response to decreased dioxin loadings from the pulp mills. In reviewing the potential health risks for coastal First Nations peoples it was determined that they would likely substitute processed food for the shellfish during the harvest closure. This would result in a slightly less, but almost equal, health threat due to the increase in consumption of foods high in saturated fat and cholesterol (Wiseman et al, 2002).

A biotoxin screening-level ecological risk assessment of the Venice Lagoon, Italy, was initiated in 2000 in response to monitoring data indicating degradation due to biological and chemical pollution. Tissue polychlorinated dibenzyl-p-dioxin and polychlorinated dibenzofuran (PCDD/F) concentrations in fish and shellfish were evaluated to determine the risk to aquatic biota and wildlife. Results indicated that potential adverse effects to fish and invertebrate receptors from PCDD/F in sediments were unlikely. Adverse effects to wildlife were possible but highly uncertain, and warranted further investigation (Wenning et al, 2000).

A human health risk assessment was also made of the population living around Venice Lagoon. High shellfish consumption rates combined with a long history of industrial activity, including oil refining and chemical production, made this a high risk population. This study provided information about concerns regarding PCDD/F dietary intake of the Venetian population compared to other European regions (Alcock et al, 2002).

Llobet, et al. (2003) estimated the dietary intake of dioxins by the population of Catalonia, Spain, to determine which food groups made the greatest contribution to this intake, and to assess the potential health risks. Food samples were randomly acquired in seven cities of Catalonia. Dioxin concentrations were determined in 108 samples including shellfish. Estimates of average daily food consumption were obtained, and the total dietary intake of dioxins for the general population was estimated to be 95.4 pg TEQ/day. Fish and shellfish (31%), dairy products (25%), cereals (14%), and meat (13%) had the greatest percentages of contribution to dioxin intake.

These studies indicate varying consumption levels between individuals and populations make it difficult to determine the overall human health risk of dioxins in shellfish. Individual populations need to be assessed to determine consumption rates, not only of shellfish, but of other foods that may contain dioxin, such as fish, dairy, and meat products. On average, the U.S. per capita consumption of oysters is much lower than for other food products. While these consumers would not be considered at high risk to health effects from dioxin contamination, unique populations that consume higher then average fish and shellfish should be evaluated separately.

Public Health Regulations

The FDA has established guidance levels for contaminants and poisonous substances in food, including dioxins in shellfish. The guidance levels are intended to control the level of contaminants in food and to supply recommended guidelines for food safety. Guidance levels are established and revised based on the criteria in the *Code of Federal Regulations*. The FDA will take legal action to remove products from the market if they contain contaminant concentrations above the guidance levels. Recommendations are based on instances when contaminants in food products cannot be avoided and do not represent suggested levels when contamination can be avoided. Table 2 lists action levels, tolerances and guidance levels established by the FDA for selected poisonous or deleterious substances in seafood, including shellfish. Notices are published in the *Federal Register* as new action levels are established or as existing action levels are revised or revoked.

While published FDA benchmarks for dioxin are 25 picograms per gram (pg/g) and 50 pg/g, these levels are generally seen as too high. The Environmental Protection Agency recommends against ingesting more than 1.2 pg dioxin per kg body weight per month. The difference between the FDA and EPA recommendations can be attributed to different ways the agencies arrive at these guidelines. The EPA's guidelines take into account factors the FDA did not address, such as concurrent exposure to more than one contaminant (Hites et al, 2004). In the European Union (EU), action levels for all fish and fishery products are 3.0 pg/g fresh weight for dioxins and dioxin-like PCBs (applicable from November 4, 2006). Action levels for other food products range from 0.5 to 4 pg/g fat.

Table 2. Action levels, tolerances and guidance levels for deleterious substances in seafood. The term "fish" refers to fresh or saltwater fin fish, crustaceans, other forms of aquatic animal life other than birds or mammals and all mollusks.

Deleterious Substance	Level	Food Commodity	Reference
DDT, DDE, TDE	5.0 pg/g	All Fish	CPG sec 575.100[c]
Arsenic	86 pg/g	Molluscan Shellfish	FDA Guidance Document
Cadmium	4 pg/g	Molluscan Shellfish	FDA Guidance Document
Chromium	13 pg/g	Molluscan Shellfish	FDA Guidance Document
Lead	1.7 pg/g	Molluscan Shellfish	FDA Guidance Document
PCBs	2.0 pg/g	All Fish	21 CFR 109.30
Dioxin (FDA)	Up to 50 pg/g	All fish and shellfish	FDA Guidance Document
Dioxin (EU action level)	3.0 pg/g	Seafoods	EU Guidance Document
Dioxin (EPA)	1.2 wt dioxin/kg/mo.	All Food	Hites, et al, 2004

Dioxins and PCBs in Shellfish

Dioxins and PCBs in Humboldt Bay

Several industrial processes have most likely contributed to increased levels of dioxins and PCBs in Humboldt Bay. Activities such as waste incineration, bleaching of paper pulp, and manufacturing of some herbicides and pesticides can release dioxins or PCBs. However, there have been few studies on the levels of dioxins and PCBs in Humboldt Bay. Table 3 summarizes the available data showing levels reported in 2002-03 of dioxins in shellfish from Humboldt Bay.

Sierra Pacific Industries (SPI) has operated their Arcata Division Sawmill located near Arcata, California, at the confluence of the Mad River Slough and Humboldt Bay since 1950. Some of the lumber milled at this facility was treated with anti-stain/anti-fungus solutions containing Pentachlorophenol (PCP) and tetrachlorophenol (TCP). These chemicals were used from the early 1960s until September of 1987. Used oil from equipment maintenance activities was stored in an underground storage tank at SPI until the 1970s. Testing indicated that the soil and groundwater at some areas around the sawmill was contaminated with PCP, TCP, dioxins, furans, and petroleum (SPI, 2004).

Sierra Pacific Industries is not the only source of dioxin and PCP contamination in Humboldt Bay; and there are approximately six sites around the bay contaminated with PCP. These include other lumber mills that used PCP before the treatment chemical was banned, and the Evergreen Pulp Mill which has been charged with several violations of the Clean Air Act (Californians for Alternatives to Toxics, 2006). The SPI site is considered the most contaminated of all the Humboldt Bay sites.

The North Coast Regional Water Quality Control Board (NCWQCB) oversees environmental activities conducted at the SPI facility. These have included soil and groundwater investigations, preparation of on site remedial measures to remove PCP contaminated soils, completion of a final feasibility study for remediation of the anti-stain/anti-fungus chemicals, implementation of a pilot study for the proposed remedial action, working to complete the off-site human health and ecological risk assessment, and groundwater monitoring. The pilot study work plan was approved in 2004 and implementation will be completed in 2006 (SPI, 2004).

Table 3. Dioxin levels in shellfish in Humboldt Bay and Mad River Slough.

Species	Average Dioxin Toxic Equivalent (pg/g) [1]	Source
Pacific Oyster	0.0333, SD = 0.0448 (n=22)	California Dept. Health Services, 2003
Wild Clam	0.0007, SD = 0.0016 (n=6)	California Dept. Health Services, 2003
Clam	0.007 (n=1)	California Dept. Health Services, 2003
Mussel	0.000 (n=1)	California Dept. Health Services, 2003
Kumamoto Oyster	0.0213, SD = 0.0117 (n=4)	California Dept. Health Services, 2003
Mussel	1.0 (n=1)	EnviroNet, 2003 (June sampling)
Pacific Triploid Oyster	1.15, SD = 0.3536 (n=2)	EnviroNet, 2003 (June sampling)
Pacific Diploid Oyster	2.117, SD = 1.189 (n=6)	EnviroNet, 2003 (June sampling)
Kumamoto Oyster	1.25, SD = 0.071 (n=2)	EnviroNet, 2003 (June sampling)
Mussel	0.10 (n=1)	EnviroNet, 2003 (October sampling)
Pacific Diploid Oyster	0.216, SD = 0.026 (n=9)	EnviroNet, 2003 (October sampling)
Kumamoto Oyster	0.223, SD = 0.021 (n=3)	EnviroNet, 2003 (October sampling)
Olympia Oyster	0.12 (n=1)	EnviroNet, 2003 (October sampling)

[1] The average dioxin toxic equivalent is reported in picograms per gram (pg/g) with standard deviations (SD) and the total number of samples used (n) to calculate each shellfish sp

In 2003 EnviroNet reported on a study, "Evaluation of the Results of Dioxin and Other Chemical Testing of Commercial Oyster Beds in Humboldt Bay, California from June and October 2002." Shellfish samples were taken from nine different commercial oyster beds in Humboldt Bay and one site from Mad River Slough (Figure 2). There were no significant differences between the oysters sampled at different locations in the Bay, and the samples from the Mad River Slough were in the lower to middle of reported dioxin concentrations. The highest dioxin levels were reported in diploid Pacific oysters grown at a location on the northeast corner of the bay near the City of Arcata. These results suggest SPI was not the only source of dioxin contamination in Humboldt Bay (EnviroNet, 2003).

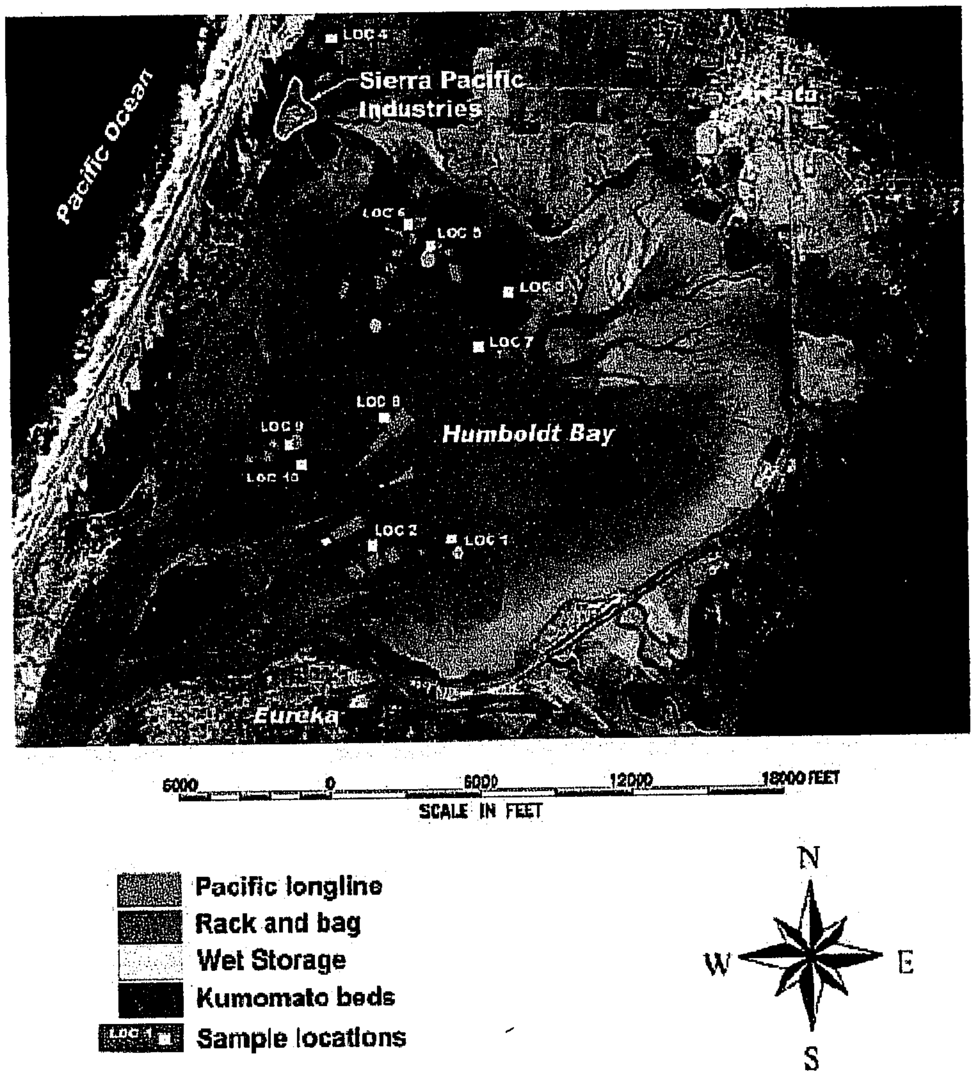

Figure 2. Humboldt Bay Shellfish Harvest Locations (Environ, 2002)

The 2003 EnviroNet study also compared dioxin levels in mussels and oysters grown suspended on longline culture and oysters grown on the sediment bottom (Figure 3). These results showed no significant differences among dioxin levels of different species and aquaculture techniques. It was concluded the presence of dioxins in oysters and mussels from Humboldt Bay represented a negligible contribution to a person's normal background exposure to dioxins. Dioxin exposure to shellfish consumers represented less than 0.1% of the typical background daily intake estimated by the USEPA (EnviroNet, 2003).

Following the EnviroNet study, the California Department of Health Services (CDHS) conducted a study of dioxins in shellfish and sediments of Humboldt Bay. In April of 2003 samples of cultured oysters, clams, mussels, wild clams, and sediments were collected from 14 shellfish harvest areas. The goal of this study was to compare the potential impact of dioxins on cultured shellfish in contact with sediment versus those using longline/or rack and bag growing methods. The results showed dioxin levels in shellfish ranging from 0.000 to 0.170 pg/g. The highest levels were seen in samples taken from a single harvest area were 0.150 and 0.170 pg/g. These levels were well below the levels detected in the EnviroNet study. Dioxin levels in the sediment samples ranged from 0.000 to 0.550 pg/g. The highest levels of dioxin in the shellfish tissue did not correlate with those areas having the highest levels in sediments (CDHS, 2003).

In preparation by the city of Eureka and the Humboldt Bay Harbor, Recreation and Conservation District for dredging areas of Humboldt Bay, dioxin levels were measured in marine sediments during November 4-14, 2005. This study was in response to concerns raised over the dredging and depositing of potentially contaminated soils. The dredge spoils were to be disposed in the surf zone on the Samoa Peninsula, which was the method used in previous dredging events.

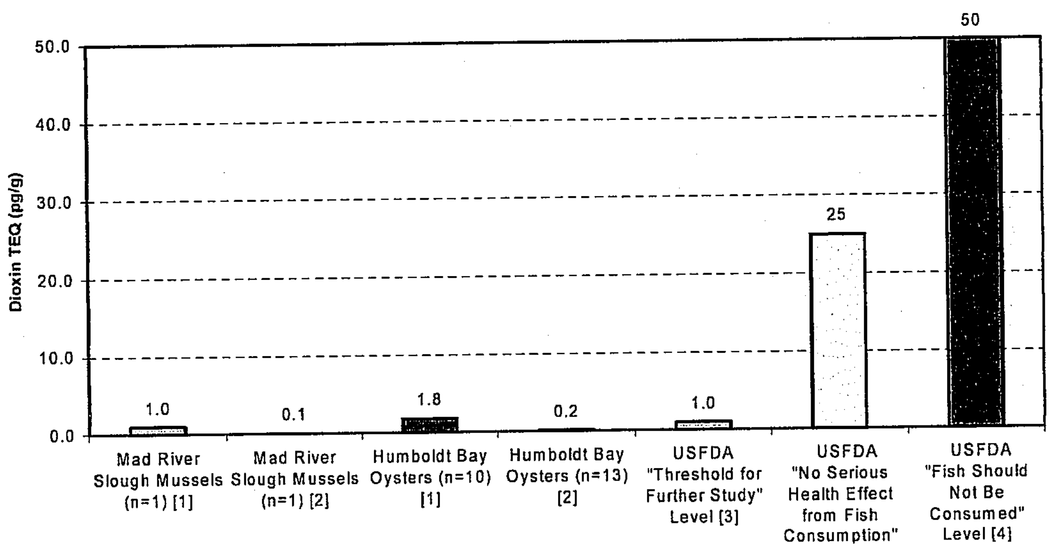

Figure 3. Comparison of dioxin toxic equivalent (TEQ) levels in oyster and mussel tissues from commercial beds in Humboldt Bay with USFDA action levels in fish and shellfish (n = number of samples). Notes: [1] EnviroNet, June 21, 2002 Sampling Event from Humboldt Bay; [2] EnviroNet, October 21, 2002 Sampling Event from Humboldt Bay; [3] Personal communication from Barbara Montwill, USFDA office of Seafood, May 17, 2002; [4] ATSDR 1998 toxicological profile for chlorinated dibenzo-p-dioxins, USFDA - levels are for 2,3,7,8-TCDD in Great Lakes fish 1981.

Sediment dioxin concentrations ranged from 0.78 pg/g to 6.03 pg/g, with the highest levels, 4.94 pg/g and 6.03 pg/g, in sediments near the Coast Seafoods Dock. Typical background levels of dioxin in U.S. sediments reported by the EPA are 5.3 pg/g. This report concluded that there was an acceptably low level of risk associated with depositing the dredge spoils in the surf zone of the Pacific Ocean (Pacific Affiliates, Inc., 2005).

Experiences in Other U.S. Areas and Canada

Other than the EnviroNet report conducted for Sierra Pacific Industries, there is limited information on dioxins in shellfish in California. This section summarizes the results of sampling programs and studies from other locations on the west coast, other U.S. states and Canada.

Firestone, et al (1996) published the results of a comprehensive survey which sampled fish and shellfish from various U.S. waterways. A total of 1,623 samples were collected from 1979-1994 and analyzed them for 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD). Results showed that TCDD residues were not widespread, but localized in areas near waste sites, chlorophenol manufacturers, and pulp and paper mills. The results also indicated that levels from these sites declined steadily during the survey period.

Lauenstein, et al, (2002) synthesized data from 11 NOAA mussel watch project sites in North and South Carolina and compared them with national mussel watch data. Three sites in North and South Carolina had concentrations of polycyclic aromatic hydrocarbons (PAHs) in the upper 15^{th} percentile on a national scale. One site had high concentrations of butyltins, and two sites had high Selenium concentrations. All sites from Beaufort, North Carolina, south had high Arsenic concentrations. Trends of decreasing concentration over time were found for arsenic, cadmium, total-chlordane, DDT, PCB, and PAHs at some sites.

The uptake and depuration of toxic compounds including TCDD in American oysters (*Crassostrea virginica*) were analyzed in oysters from Galveston Bay, Texas. Oysters were transplanted between a heavily polluted area and a relatively uncontaminated area within the bay. Results showed that the elimination of the toxic compounds investigated was slower for the chronically exposed population than from the newly contaminated one (Gardinali, et al. 2004). This study indicated that depuration maybe used as a technique to decrease contaminants in oysters, but will be more successful in oysters having only short term exposure.

Oysters analyzed in St. Louis Bay, Mississippi and adjacent waters of the Mississippi Sound contained average dioxin levels of 0.392 pg/g. The highest levels in both shellfish and sediments were detected near a titanium dioxide refinery outfall. Dioxin levels in St. Louis Bay had increased approximately 1.8 to 2.5 times between 1997 and 2004. The authors viewed this as a unique observation and suggested the refinery was the main source of dioxin contamination in the bay (Elston et al, 2005).

The California State Mussel Watch and the Regional Monitoring Program for Trace Substances produced data for trace elements and organic contaminants from San Francisco Bay in the bivalves *Mytilus californianus, Crassostrea gigas*, and *Corbicula fluminea*. Significant declines in contaminant concentrations in *M. californianus* for the period 1980 – 1996 were observed for PCBs, p,p'-Dichlorodiphenyldichloroethylene (p,p-DDE), cis-chlordane, dieldrin, and silver, while a significant increase was observed for chromium. The results indicated that biomonitoring bivalves can produce valuable data on the concentrations of certain contaminants in coastal ecosystems (Gunther et al, 1999).

Several studies from Canada report on dioxins and dioxin contamination of shellfish in waters near pulp and paper mills. Initially, the reports resulted in fishery closures and advisories to limit shellfish consumption in British Columbia, Alberta, Ontario, and Quebec (Whittle et al, 1993). In the 1980s shellfish harvesting restrictions for up to 1,200 square km of the British Columbia coast were imposed. These closures lead to efforts to modify the pulping process for mills discharging to marine waters in British Columbia. These changes reduced dioxin loadings and concentrations in sediments and shellfish by 97% between 1989 and 1994. The following are the average declines in toxicity equivalents between 1990 and 1995: sediment (61%), Dungeness crab hepatopancreas (a digestive tract organ) (80%), Dungeness crab muscle (85%), oyster (93%), prawn (92%), and shrimp (87%). Since 1995, harvesting restrictions due to dioxin/furan contamination have been progressively lifted from the 1,200 square km of the affected area (Wiseman et al, 2002).

International Observations

There are a number of published accounts on dioxin and PCB contamination in shellfish reported from Asia and Europe. Chen, et al. (2002) collected shellfish samples from the coastal areas of Xiamen Island and Minjing Estuary, China and analyzed them for hexachlorocyclohexanes (HCHs), DDTs and polychlorinated biphenyls (PCBs). Organochlorine accumulation was observed in marine bivalves, particularly oysters. Concentrations varied by area, season, and species sampled, but were generally higher than concentrations in sediments. DDTs were the dominant organochlorine compound found in sampled shellfish.

Japanese researchers in Sendai Bay analyzed the concentrations of polychlorinated dibenzodioxin and dibenzofuran (PCDD/F) and coplanar-PCB congeners in seawater, sediment, Pacific oyster, anchovy, marbled sole, and flounder samples. The composition of total PCDD/F and total coplanar-PCB concentrations in sediment and oyster tissue reflected seawater concentrations, with observed levels of PCDD, PCDF, and coplanar-PCB at 60, 10, and 30% respectively (Okumura et al, 2003).

The Hong Kong Environmental Protection Department recently reported the results of a six year survey of trace toxics in mussels. Concentrations of heavy metals and trace organics were measured in mussels sampled from 5 locations in Hong Kong waters. Of 17 dioxin compounds analyzed, two that were detected were of low toxicity. The most toxic congeners of dioxin were not detected at any of the sites (Liu and Kueh, 2005).

Several European countries have conducted studies on dioxin and other contaminants in shellfish. In Spain, between 1995 and 2003, commercial salmon, tuna fish, sardine, oyster, mussel, and clam samples were analyzed for several contaminants including PCDD. Dioxin levels declined at a greater rate over entire sample period than the PCB levels. Mean concentrations of PCDD and PCDF ranged from 0.62 pg/g in clams and 2.89 pg/g in oysters (Gomara et al, 2005).

Observations of PCDF/PCDDs and other dioxin-like compounds were reported from Frierfjorden in southern Norway as a follow up to an earlier monitoring study. The discharge of these chemicals into this water body was reduced from 50-100 kg in the period 1951-1975 to about 6-7 kg in 1976-1990, and further to about 20 g in 1991-2000. Monitoring demonstrated decreasing contamination in organisms, which was initially highly significant in all sampled species. However, concentrations were still elevated and further analysis of PCDF/PCDD congener profiles in four fish species, mussels and crabs resulted in 5 distinct groups, demonstrating examples of species specific accumulation characteristics (Knutzen, 2003).

Summary and Conclusions

This review indicates that bivalve shellfish in most regions of the United States and other countries generally contain dioxin concentrations well below levels considered to be a human health risk. Table 4 summarizes the available data collected from studies of dioxin in shellfish conducted in the United States and internationally. Most long-term studies demonstrate a decline in dioxin levels, and for a large part, levels have decreased since industries releasing these pollutants have come under more stringent regulation. The results of 2002 Humboldt surveys reported marginally higher but variable dioxin levels than those detected in the majority of studies at other locations. However, CDHS reports from 2003 sampling of Humboldt shellfish and sediments indicate dioxin levels were considerably lower than reported concentrations. There are no similar long-term data from Humboldt Bay that can offer a historical perspective of dioxin levels, but trends in recent years suggest in the absence of continued inputs into the bay, dioxin will continue to decrease to naturally occurring levels.

Studies have shown that without industrial sources of dioxins, the levels in shellfish and sediments should continue to decline. Reviewed literature also indicates that an elevated level of dioxins in sediments does not necessarily lead to increased levels in the shellfish grown in the area. The EnviroNet survey revealed that the highest levels of dioxin in shellfish were not found near the SPI mill, but near the city of Arcata. In addition, while there were higher levels of contaminants on the land and sediments surrounding the SPI facility, there appeared to be no impact on nearby shellfish.

EnviroNet sampling in 2002 showed dioxin levels in Humboldt Bay shellfish at levels well below the USFDA benchmarks. The results ranged between 0.8 and 4.3 pg/g, with samples taken during the summer spawning period having the highest average dioxin concentrations. The USFDA benchmark level for no serious health effect is 25 pg/g. Based on the sample findings, the EnviroNet report concluded the consumption of Humboldt Bay shellfish did not pose a health risk in regards to dioxin levels.

The 2003 study by the California Department of Health Services showed very low levels of dioxin in shellfish and sediments, ranging from 0.000-0.170 pg/g and 0.000-0.550 pg/g respectively. These levels were all well below USFDA benchmarks as well as USEPA and European Union's action levels.

After review of pertinent studies, reports and health criteria, it is concluded that Mad River Slough and Humboldt Bay, as a shellfish growing areas, meet all standards of safe harvest and consumption of commercially grown shellfish within the wet and dry weather standards administered by California Department of Health Services. The Humboldt Bay Harbor, Recreation and Conservation District, as state tideland trustee, is carrying out its obligation to ensure that shellfish culture activities presently permitted on leased tidelands are meeting human health criteria related to shellfish safety with regard to dioxin.

Table 4. Summary of dioxin levels reported in shellfish.

Species	Location	Average Dioxin TEQ (ppt)	Reference
Fish/Shellfish	Italy	0.53	Pompa, et al, 2003
Fish/Shellfish	Germany	0.48	Pompa, et al, 2003
Fish/Shellfish	Sweden	2.96	Pompa, et al, 2003
Fish/Shellfish	United Kingdom	0.54	Pompa, et al, 2003
Fish/Shellfish	Norway	0.54	Pompa, et al, 2003
Fish/Shellfish	France	0.63	Pompa, et al, 2003
Fish/Shellfish	Netherlands	0.57	Pompa, et al, 2003
Fish/Shellfish	Finland	3.51	Pompa, et al, 2003
Fish/Shellfish	Denmark	1.63	Pompa, et al, 2003
Clams	Spain	0.62	Gomara, 2005
Oysters	Spain	2.89	Gomara, 2005
Oysters	Mississippi	0.392	Elston, et al., 2005
Clams	Mississippi	0.581	Elston, et al., 2005
Geoduck	Port Angeles, WA	0.019	WDOH, 2005
Dungeness Crab	Port Angeles, WA	0.18	WDOH, 2005
Red Rock Crab	Port Angeles, WA	0.013	WDOH, 2005
Pacific Oyster	California	0.0333	California Dept. Health Services, 2003
Wild Clam	California	0.0007	California Dept. Health Services, 2003
Clam	California	0.007	California Dept. Health Services, 2003
Mussel	California	0.000	California Dept. Health Services, 2003
Kumamoto Oyster	California	0.0213	California Dept. Health Services, 2003
Mussel	California	1.0	EnviroNet, 2003 (June sampling)
Pacific Triploid Oyster	California	1.15	EnviroNet, 2003 (June sampling)
Pacific Diploid Oyster	California	2.117	EnviroNet, 2003 (June sampling)
Kumamoto Oyster	California	1.25	EnviroNet, 2003 (June sampling)
Mussel	California	0.10	EnviroNet, 2003 (October sampling)
Pacific Diploid Oyster	California	0.216	EnviroNet, 2003 (October sampling)
Kumamoto Oyster	California	0.223	EnviroNet, 2003 (October sampling)
Olympia Oyster	California	0.12	EnviroNet, 2003 (October sampling)

Literature Cited

1. Alcock R, Sweetman A, Green N, et al. 2002. PCDD/Fs in Venetian Foods - a Quantitative Assessment of Dietary Intake. *Battelle Memorial Institute*. Columbus, OH.

An examination of the fish and shellfish consumption of the population living around Venice Lagoon, Italy. This area has a higher than national average consumption rate, and a long history of industrial activity, including oil refining and chemical production. The report was designed to provide information about concerns regarding PCDD/F dietary intake of the Venetian population compared to other European regions.

2. California Department of Health Services. 2003. Dioxins in Molluscan Shellfish Humboldt Bay Sampling. Unpublished data.

Data provided by Michael Hernandez of the food and drug branch of the California Department of Health Services. Although intended to compare dioxins in shellfish cultured on the bottom and longline culture, the data do not indicate culture type. Very low levels of dioxins are reported in the shellfish and sediments sampled.

3. Californians for Alternatives to Toxics. 2006. Citizen Lawsuit Filed Against Evergreen's Humboldt Bay Pulp Mill. Media Release. http://www.alternatives2toxics.org/mediarelease-01-06.htm.

A media release describing the class-action lawsuit filed against Evergreen's Humboldt Bay Pulp Mill for on-going violations of the mill's federal air quality permit. Claimed Evergreen exceeded emission limits for particulate matter and total reduced sulfur repeatedly since purchasing the mill in January of 2005.

4. Chen, W., Zhang, L., Xu, L., Wang, X., Hong, L., Hong, H. 2002. Residue Levels of HCHs, DDTs and PCBs in Shellfish from Coastal Areas of Xiamen Island and Minjiang Estuary, China. *Mar. Pollut. Bull.* 45(1-12):385-390.

This study collected shellfish samples from the coastal areas of Xiamen Island and Minjing Estuary, China and analyzed them for hexachlorocyclohexanes (HCHs), DDTs and polychlorinated biphenyls (PCBs). The results showed that organochlorines accumulated in marine bivalves, particularly oysters. Concentrations ranged by area, season, and species sampled, but were generally higher than concentrations in sediments. Concentrations of DDTs in shellfish were high compared to the other contaminants sampled.

5. Cunningham PA, Smith SL, Tippett JP, Greene A. 1994. A national fish consumption advisory data base: A step toward consistency. *Fisheries.* 19(5):14-23.

A compiled list of fish consumption advisories resulting from chemical contamination of fish and shellfish species throughout the United States. At the time the list was created four pollutants triggered 90% of the advisories; these are mercury, PCBs, chlordane, and dioxin.

6. Elston, R., E. W. Cake, Jr., K. Humphrey, W.C. Isphording and J. E. Rensel. 2005. Dioxin and heavy-metal contamination of shellfish and sediments in St. Louis Bay, Mississippi and adjacent waters. *Journal of Shellfish Research.* 24(1):227-241.

A report on dioxin and other contaminant levels in shellfish and sediments in St. Louis Bay, Mississippi and adjacent waters of the Mississippi Sound. Dioxin TEQ values based on whole shellfish soft tissue wet-weights averaged 0.392 pg/g for oysters and 0.581 pg/g for a single sample of Rangia clams. Dioxin levels in sediments ranged from 4.17-11.78 ppt with the highest levels in samples taken near a titanium dioxide refinery outfall.

7. Environ. 2002. Final report on evaluation of the results of dioxin and pentachlorophenol testing of oysters and mussels from commercial beds in Humboldt Bay, California. *Prepared by Environ International Corp.*, Emeryville, Ca for Sierra Pacific Industries, Arcata, Ca. 28 p.

A summary of field sampling and chemical testing results from dioxin and pentachlorophenol testing of commercial oysters and mussels in Humboldt Bay. Includes an evaluation of health risks to consumers posed by the trace levels of dioxin in oysters and mussels. The study findings and conclusions were as follows: 1) The occurrence of trace levels of dioxins in oyster and mussel tissues is below the 25 ppt FDA benchmark; 2) Pentachlorophenol was not detected in any of the oysters or mussels sampled; 3) The distribution of dioxin congeners found in oyster and mussel tissues is similar, but does not match the dioxin profile typically associated with wood treatment products containing pentachlorophenol: 4) The results indicate there is more than one source of dioxin in Humboldt Bay; 4) The theoretical health risks associated with consumption of oysters and mussels from Humboldt Bay poses an incremental lifetime cancer risk below 1 in 1,000,000 (10^{-6}risk), which is below the EPA risk range of 10^{-4} to 10^{-6}; and 6) Dioxin exposure to shellfish consumers represents less than 0.1% of the typical background daily intake from all dietary sources estimated by the USEPA.

8. EnviroNet and Environ. 2003. Evaluation of the results of dioxin and other chemical testing of commercial oyster beds in Humboldt Bay, California, from June and October, 2002. Prepared by EnviroNet, Santa Rosa, Ca and Environ International Corp., Emeryville, Ca for Sierra Pacific Industries, Arcata, Ca. 35 p. + appendices.

A report prepared for Sierra Pacific Industries in response to concerns raised by local shellfish growers regarding dioxin contamination in Humboldt Bay. Field sampling and chemical testing were conducted in June and October 2002, from nine different sites throughout Humboldt Bay. Dioxin concentrations ranged from 0.8 and 4.3 ppt, with an average concentration of 1.8 ppt. This is below the FDA benchmark of 25 ppt identified for no serious health effects, and well below the 50 ppt action level at which the FDA recommends against consumption.

9. EPA. 2004a. Summary of the Dioxin Reassessment Science. *Information Sheet.* U.S. Environmental Protection Agency.

A summary of EPA's study entitled "Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds". In this study scientists from the EPA and other federal agencies and the scientific community conducted a reassessment of dioxin exposure and human health effects since 1991.

10. EPA. 2004b. Scientific Highlights from the NAS Review Draft of EPA's Dioxin Reassessment. *Information Sheet 2.* Environmental Protection Agency.

An in-depth summary of the study, "Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds". It includes updated information on "Dose Response", "Toxicity Equivalence", and "Integrated Summary and Risk Characterization."

11. Firestone D, Fehringer NV, Walters SM, et al. 1996. TCDD residues in fish and shellfish from U.S. waterway. *J AOAC Int.* 79(5):1174-1183.

Samples of fish and shellfish were taken from various U.S. waterways and analyzed for TCDD. 1,623 samples were collected from 1979-1994. Results showed that TCDD residues were not widespread, but localized in areas near waste sites, chlorophenol manufacturers, and pulp and paper mills. The results also indicated that levels from these sites have been declining steadily.

12. Gardinali PR, Sericano JL, Wade TL. 2004. Uptake and depuration of toxic halogenated aromatic hydrocarbons by the American oyster (crassostrea virginica): A field study. *Chemosphere.* 54(1):61-70.

An analysis of the uptake and depuration of toxic compounds including TCDD in American oysters (*Crassostrea virginica*). Oysters were transplanted back and forth between a heavily polluted area and a relatively unimpacted area within Galvaston Bay, TX. Results showed that the elimination of the toxic compounds investigated were slower for the chronically exposed population than from the newly contaminated one.

13. Gomara B, Bordajandi LR, Fernandez MA, et al. 2005. Levels and trends of polychlorinated dibenzo-p-dioxins/furans (PCDD/Fs) and dioxin-like polychlorinated biphenyls (PCBs) in Spanish commercial fish and shellfish products, 1995-2003. *J Agric Food Chem.* 53(21):8406-8413.

A total of 123 Spanish commercial salmon, tuna fish, sardine, oyster, mussel, and clam samples from 1995 to 2003 were analyzed for several contaminants including PCDD. Dioxin levels over the years decreased more than the PCB levels. Mean concentrations of PCDD and PCDF ranged from 0.62 pg/g in clams and 2.89 pg/g in oysters.

14. Gunther AJ, Davis JA, Hardin DD, et al. 1999. Long-term bioaccumulation monitoring with transplanted bivalves in the San Francisco estuary. *Mar Pollut Bull.* 38(3):170-181.

The California State Mussel Watch and the Regional Monitoring Program for Trace Substances have conducted biomonitoring for trace elements and organic contaminants in the San Francisco Estuary using transplanted bivalves (*Mytilus californianus, Crassostrea gigas*, and *Corbicula fluminea*). Significant declines in contaminant concentrations in *M. californianus* for the period 1980 – 1996 were observed for PCBs, p,p-DDE, cis-chlordane, dieldrin, and Silver, while a significant increase was observed for Chromium. These results indicate that biomonitoring using transplanted bivalves can produce valuable data on the spatially and temporally averaged abundance and distribution of certain contaminants in coastal ecosystems.

15. Hites, Ronald A., Foran, Jeffery A., Carpenter, David O., Hamilton, M. Coreen, Knuth, Barbara A., Schwager, Steven J. 2004. Global Assessment of Organic Contaminants in Farmed Salmon. *Science.* Vol. 303. 226-229.

The authors analyzed over two metric tons of farmed and wild salmon around the world and analyzed the fish for contaminants. Contaminants measured included dioxins, PCBs, toxaphene, and dieldrin. This article also discusses the differences between the contaminant benchmarks set by EPA and FDA.

16. Knutzen J, Bjerkeng B, Naes K, Schlabach M. 2003. Polychlorinated dibenzofurans/dibenzo-p-dioxins (PCDF/PCDDs) and other dioxin-like substances in marine organisms from the greenland fjords, S. Norway, 1975-2001: Present contamination levels, trends and species specific accumulation of PCDF/PCDD congeners. *Chemosphere.* 52(4):745-760.

The contamination levels were monitored in organisms in Frierfjorden, Norway in response to the reduction of discharged PCDF/PCDDs. The discharge of these chemicals was reduced from 50-100 kg in the period 1951-1975 to about 6-7 kg in 1976-1990, and further to about 20 g for 1991-2000. Monitoring indicated decreasing contamination in organisms, first highly significant in all sampled species then leveling off, at still relatively high levels. Multivariate analysis of PCDF/PCDD congener profiles in four fish species, mussels and crabs resulted in five distinct groups, demonstrating species specific accumulation characteristics.

17. Jensen, E., Bolger, P.M. 2001. Exposure Assessment of dioxins/Furans consumed in dairy foods and fish. *Food Addit. Contam.* 15(5):395-403.

The USFDA conducted a survey of dairy products and commercial fish and shellfish to obtain data on levels of 17 dioxin/furan cogeners. Samples were collected in 1995 and 1996. Products sampled included various cheeses, ice cream, yogurt, butter, milk, canned tuna, catfish, shrimp, cod, blue crab, and oysters. The bounds on mean dioxin intakes (pg/person/day) calculated for consumers of mollusks were estimated at 16.1-16.6 pg/person/day.

18. Judd, N.L., Griffith, W.C., Faustman, E.M. 2004. Consideration of Cultural and Lifestyle Factors in Defining Susceptible Populations for Environmental Disease. Toxicology. 198:1-3. 121-133.

Dioxin-like PCBs were employed to assess the risk of contaminants to different consumption groups. Pacific Northwest and Western Canada Asian and Pacific Islander populations and tribal nations were reported to consume ten times more fish and seafood than the average U.S. consumer, and have dietary practices that can lead to significant exposures to persistent pollutants. The authors indicate that regulatory evaluations of fish consumption did not always take into account unique consumption and cooking practices of these groups.

19. Lauenstein GG, Cantillo AY, O'Connor TP. 2002. The status and trends of trace element and organic contaminants in oysters, crassostrea virginica, in the waters of the Carolinas, USA. *Sci Total Environ.* 285(1-3):79-87.

A comparison of 11 NOAA mussel watch project sites in North and South Carolina with national mussel watch data. Three sites in North and South Carolina had concentrations of PAHs in the upper 15th percentile on a national scale. One site had high concentrations of butyltins, and two sites had high Selenium concentrations. All sites south of Beaufort, North Carolina had high arsenic concentrations. Other sites exhibited decreasing trends for arsenic, cadmium, total-chlordane, DDT, PCB, and PAHs.

20. Liu, JH., Kueh, C.S. 2005. Biomonitoring of Heavy Metals and Trace Organics Using the Intertidal Mussel *Perna viridis* in Hong Kong coastal Waters. *Mar. Poll. Bull.* May 19th.

A report of a six year survey of trace toxics in mussels conducted by the Hong Kong Environmental Protection Department. Concentrations of heavy metals and trace organics were measured in mussels collected from five sites. Of 17 dioxin compounds analyzed, two were detected. These were determined to be of low toxicity. The most toxic congeners of dioxin were not detected at any of the sites.

21. Llobet JM, Domingo JL, Bocio A, Casas C, Teixido A, Mueller L. 2003. Human exposure to dioxins through the diet in Catalonia, Spain: Carcinogenic and non-carcinogenic risk. *Chemosphere.* 50(9):1193-1200.

The main objectives for this study were to estimate the dietary intake of dioxins by the population of the autonomous region Catalonia, Spain, to determine which food groups showed the greatest contribution to this intake, and to assess the health risks potentially associated with the dietary dioxin intake. Food samples were randomly acquired in seven cities of Catalonia. Dioxin concentrations were determined in 108 samples including shellfish. Estimates of average daily food consumption were obtained, and the total dietary intake of dioxins for the general population was estimated to be 95.4 pg TEQ/day. With fish and shellfish (31%), dairy products (25%), cereals (14%), and meat (13%) showing the greatest percentages of contribution to dioxin intake. These results corroborate the decreasing tendency in dietary intake of dioxins found in recent studies from various countries.

22. NSSP. 2003. Guide for the Control of Molluscan Shellfish. National Shellfish Sanitation Program. U. S. Department of Health and Human Services Public Health Service, Food and Drug Administration, and the Interstate Shellfish Sanitation Conference.

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The concentrations of PCDD/F and Co-PCB congeners were analyzed in seawater, sediment, Pacific oysters, Japanese anchovy, marbled sole, and Japanese flounder samples from Sendai

Bay, Japan. The compositions of total PCDD/F and total Co-PCB concentrations in sediment and Pacific oysters reflected that in seawater, with relative concentrations of PCDD, PCDF, and co-PCB concentrations of about 60%, 10%, and 30% respectively. Different PCDD/F congeners tended to bioaccumulate in different organisms.

24. Pacific Affiliates, Inc. 2005. Sampling Results Report for Dioxin/Furans, PCP and PCB Testing. City of Eureka and Humboldt Bay Harbor, recreation and Conservation District. Cooperative Eureka Waterfront Facilities Maintenance Dredging Project. Eureka Channel, Humboldt Bay, California.

Analytical results from sediment testing at the site of a proposed dredging project by the City of Eureka, Humboldt Bay. Sediments were tested for dioxins, PCP, and PCBs. This testing was in response to health concerns over the disposal of dredge spoils in the surf zone of the Pacific Ocean. The report concluded that the sediments did not pose a significant health risk.

25. Pompa, G., Caloni, F., fracchiolla, M.L. 2003. Dioxin and PCB Contamination of Fish and Shellfish: Assessment of Human Exposure. Review of the International Situation. *Veterinary Research Communications*, 27 Suppl. 1, 159-167.

A review of dioxin and other contaminant levels in food in European countries and the U.S. Also evaluated consumption rates of foods in different countries, and the intake of dioxins based on those consumption rates. Dioxin levels were found to be about 10 times higher in fish and shellfish than other animal products. Consumption data were compared to Total Daily Intake (TDI) guidelines from several different sources, including the World Health Organization and the European Commission, Health and Consumer Protection Scientific Committee on Food (SCF). High level consumers, in the 95^{th} percentile, regularly exceeded the upper limit of the TDI set by the WHO.

26. Sierra Pacific Industries. 2004. Environmental Activities Update. Arcata Division Sawmill. Arcata, CA.

27. Washington State Department of Health (WDOH). 2005. Evaluation of Dioxins in Crab and Geoduck Tissue from the Lower Elwha Klallam Tribe Fishing Area Near Port Angeles, Washington. DOH Pub No 333-071.

Dioxin levels were measured in geoduck clams, Dungeness and red rock crabs from a Lower Elwha Klallam Tribe fishing area near Port Angeles, Washington. This area is located near the site of the now decommissioned Rayonier pulp and paper mill. Dioxin levels were analyzed and compared to national levels in other foods. The levels in shellfish were determined to pose no significant health threat to consumers of these products.

28. Wenning R, Dodge D, Peck B, et al. 2000. Screening-Level Ecological Risk Assessment of Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans in Sediments and Aquatic Biota from the Venice Lagoon, Italy. *Pergamon,* P.O. Box 800 Kidlington Oxford OX5 1DX UK: Elsevier Science Ltd.

This study was a screening-level ecological risk assessment of Italy's Venice Lagoon ecosystem in response to monitoring data indicating degradation due to biological and chemical pollution. The risk assessment was performed to evaluate the risks to representative aquatic biota and wildlife receptors. Tissue PCDD/F concentrations in fish and shellfish were measured to determine the risk to aquatic invertebrates. Results indicated potential adverse effects to fish and invertebrate receptors from PCDD/F in sediments were unlikely. Adverse effects to wildlife were possible but highly uncertain, and warranted further investigation.

29. Whittle D, Mageau C, Duncan R, Sergeant D, Nassichuk M. 1993. Canadian National Dioxin Sampling Program: Dioxins and Furans in Biota Near 46 Pulp and Paper Mills using the Chlorine Bleaching Process. *Department of Fish and Oceans. Burlington*, ON, Canada.

A four year sampling program conducted from 1988 to 1992 to determine the extent of dioxin and furan contamination at marine and freshwater sites in the vicinity of pulp and paper mills using the chlorine bleaching process. Fish, shellfish, waterfowl, and sediments were sampled at all sites. The results led to some fishery closures and advisories to limit consumption where elevated levels existed. These actions affected commercial, recreational and native food fisheries in the provinces of British Columbia, Alberta, Ontario, and Quebec.

30. Wiseman, Clare L.S., Gobas, Frank A.P.C. 2002. Balancing Risks in the Management Of Contaminated First Nations Fisheries. *International Journal of Environmental HealthResearch.* 12, 331-342.

Potential health impacts of risk management options are described for coastal First Nations peoples to reduce dioxin contamination in British Columbia, Canada. In the 1980s several shellfish harvest areas near pulp and paper mills were closed to harvest due to elevated levels of dioxin. These closure areas were progressively reopened since 1995 in response to decreased dioxin loadings from the pulp mills. This study determined that coastal aboriginal people would substitute processed food for the shellfish during the harvest closure. This would result in a slightly less, but almost equal, health threat due to the increase in consumption of foods high in saturated fat and cholesterol.