CB HABITAT GROUP MEMORANDUM **November 2, 2009**
Polaris Applied Sciences, Inc. and Littoral Ecological & Environmental Services

ANALYSIS OF PROPOSED INJURY AND DAMAGE FOR EXPOSED SAND BEACHES, MUD AND SAND FLATS AS IT RELATES TO THE FEASIBILITY AND APPROPRIATENESS OF TOXICITY/FOULING STUDIES

The following memo highlights the RP comments regarding the sand beach and tidal flat service loss and duration assumptions of the Trustees and the viability of toxicity studies.

SAND BEACHES

The Trustees have proposed that exposure to COSCO BUSAN Bunker C fuel oil resulted in extensive, temporally extended loss of services in the intertidal biota on outer coast sandy beaches (Table 1). Coinciding with these estimates, the estimates for Discounted Service Acre-Years (DSAYs) lost is also substantial. As part of an effort to evaluate the soundness of these proposed initial service loss estimates for sandy beaches, exposure must be adequately characterized, a pathway and mechanism for injury must be determined, and an injury determination rendered. For sandy beaches in particular, the community structure and the population structure of the biota dominating these beaches should be considered when evaluating the pathway and likely duration of potential injuries. The RP has also investigated toxicity literature relevant to the specific animals found on exposed sandy beaches. The purpose was to examine the nature of the populations comprising theses assemblages, their stability, and the rate and manner of reproduction and repopulation in the event of an injury.

Table 1. Comparison of Trustee and RP estimates for sand beach acres exposed, service loss, recovery period, and Discounted Service Area Years (DSAY) (for settlement purposes only).

Oiling Category	Trustee Acres	SCAT Acres	Proposed Trustee Initial Service Loss	Proposed Trustee Recovery Period (mo)	Proposed RP Initial Service Loss	Proposed RP Recovery Period (mo)	Trustee DSAYs	RP DSAYs*
Heavy	4.3	0.39	100%	36	100%	12	3.0	2.0
Moderate	5.4	2.46	60%	36	60%**	12	2.2	1.1
Light	147.2	1.22	40%	7	25%**	7	22.0	13.7
Very Light	459.8	3.18	20%	7	0	0	34.3	0.0
TOTAL	616.7	7.25	Ratio = 85.1				61.4	16.9

* For settlement purposes, the RP used the Trustee estimated acres.

** The RP has assumed injury for settlement purposes only, although empirical evidence of exposure to burying infauna in these categories does not exist.

HABITATS AND NATURE OF THE BIOTA CONSIDERED

According to SCAT data for the CB, over 90% of the sand shoreline habitat exposed to COSCO BUSAN fuel oil occurs on the outer coast and thus falls within the habitat classified by Ricketts, Calvin, and Hedgpeth (1985) as Open-Coast Sandy Beaches. These authors allude to the rigor of this environment and state: "*The obstacles faced by sand dwellers on an exposed coast are all but insuperable is indicated by the fact that few animals are able to hold their own there. These beaches are sparsely populated in comparison with similar rocky shores. Actually, we know of only six or seven common forms that occur in any abundance on heavily surf-swept sand beaches*."

They furthermore write, "*Most members of the sandy beach community are uncertain in their occurrence; they have good years and bad years, and a beach that was teeming with sand crabs or hoppers one year may be unoccupied a year later. The population may have been wiped out by a rapid change in the shape of the beach – the waves may have shifted direction, thus cutting the beach back to the dunes, or building it up faster than it can be populated*."

As pointed out above, the profile of these high-energy beaches is reduced in the winter since the winter storm waves move a large proportion of the sand onto offshore sand bars. Consequently, any oil that may remain on the beach during the winter will not likely be part of the available habitat for biota when the sand forming the offshore bars is returned to the beach in the spring and summer when the storm waves abate.

The four predominant habitats on these beaches, distinguished by tidal elevation, are the: upper; upper mid; swash (lower mid); and lower intertidal zones. Animals dominating in the upper zone, often associated with beach wrack, include the mostly nocturnal talitrid amphipods that brood and release their young, thus achieving local replacement of the stocks Ricketts *et al.* (1985). They typically burrow deeply or hide under wrack during the day. Other types include flies, coleopteran beetles, and a variety of other arthropods (Anon. 2009). Most high intertidal invertebrates are scavengers.

Animals dominating the upper mid zone, which is subject to extensive and rapid sand removal during winter storms, are highly mobile cirolanid isopods of the genus *Excirolana*, predator/scavengers that also brood and release their young and therefore achieve local replacement of the stocks. They burrow when the tide covers their area but swim actively seeking food when the tide allows.

The swash (lower mid) and lower zones are characterized by sand crabs (*Emerita analoga*), generally the dominant organism, opossum shrimp (a mysid, *Archaeomysis grebnitzkii* or *maculata*), and an errant polychaete *Nephtys californiensis*. Sand crabs move up and down the beach in the wave swash, swimming during the wave surge and burying as the swash flows the down beach in order to feed on suspended phytoplankton with their antennae (Efford 1966). In spring and summer, large dense aggregations of juvenile sand crabs often move up and down the beach with the changing tide and remain buried in the sand flats in great numbers above the water line at low tide (Efford 1965; MacGinitie and MacGinitie 1968). The mysids generally remain suspended in the water unless they become stranded on an ebbing tide, when they bury in the sand. They feed on zooplankton in and just beyond the swash zone. *Nephtys*, often called the shimmy worm, is a predator that lives buried in the sand; it feeds on smaller infaunal organisms. The low intertidal and shallow subtidal zone sometimes support small numbers of Pismo clams (*Tivela stultorum*), Pacific razor clams (*Siliqua patula*), and the spiny sand crab (*Blepharipoda occidentalis*) but these species are generally far less common than the animals listed above.

Chan (1975) report on the 18 January 1971 spill of 840 gallons of Bunker C oil under the Golden Gate Bridge that the dominant organisms on Stinson Beach and Drakes Beach were the sand crab *Emerita analoga*, the shimmy worm *Nephtys californiensis*, and the beach hopper *Orchestoides californiana* provides support to this listing of dominant organisms on exposed sandy beaches above.

The dominant species, except Pismo and razor clams, are relatively short-lived like sand crabs. Males appear to be largely annuals whereas females may live 2 to 3 years (Efford 1965, 1967; Barnes and Wenner 1968).

Regarding repopulation, dominant species such as sand crabs and shimmy worms in the mid and lower intertidal zones have pelagic larvae that spend several weeks to months (*Emerita*) in the plankton and it is most unlikely that any larvae return to the beach from which they originated. Rather, these beaches are most likely repopulated by larvae from a mix of other areas or regions. The dynamic environment has been the template for the evolution of the species ability to rapidly re-populate following complete removal. Some others such as the cirolanid isopod *Excirolana* and the mysid *Archaeomysis* brood their young, which are released locally.

Despite the large amount of research published on *E. analoga*, the timing of reproduction and recruitment appears spatially and temporally variable and local (Efford 1965) and seasonal occurrence of adult sand crabs appears poorly defined or quite variable. It varies considerably among years at the same location and among locations within the same region. In southern California, sand crabs may exhibit high abundance in an area for one or more years but be scarce of virtually absent in subsequent years (Efford 1965). Little information is available for seasonal or spatial patterns north of Point Conception.

Efford (1965) reported that megalopae, the last larval stage of *Emerita*, settled on beaches in early spring and summer in La Jolla, peaking in early June. However, Barnes and Wenner (1968) observed that megalopae began recruiting to the beaches in September in Santa Barbara and continue recruiting during winter and early spring as well as fall and winter. Generally, juveniles appear in spring and early summer (Efford 1965) and males become sexually mature quite rapidly (Efford 1967). Efford (1965) reported that reproduction occurs over a protracted period in summer. In contrast, Barnes and Wenner (1968) observed that mating season starts in late spring and early summer in Santa Barbara, followed by continual production of larvae during the summer. Following cessation of reproduction, Barnes and Wenner (1968) reported that large females disappear out of the beach populations and cited an observation that large females were sighted offshore at a depth of 7.6 m. Both Efford (1965) and Barnes and Wenner (1968) observed large females in beach populations in the spring, suggesting that females that may overwinter offshore return to the beaches in the spring.

Barnes and Wenner (1968) concluded: “It appears to us that the species can be thought of as being contained in two distinct reservoirs: 1) an intertidal reservoir producing pelagic larvae during summer and fall, and 2) a pelagic reservoir supplying various beaches with megalopae in fall, winter, and spring. Under this interpretation, both intertidal and pelagic reservoirs overlap each other at each end of their temporal range; each habitat is relatively empty for two-three months of the year - the former in midwinter and the latter in midsummer." They claim that, in Santa Barbara, "The majority of the beach population during winter and early spring consists of megalopae, juveniles, and males.

This description of temporal patterns of *E. analoga* on exposed sandy beaches has many relevant points when assessing the potential magnitude of impact of the COSCO BUSAN oil spill on the sand crab, which is the dominant invertebrate on these beaches, and on the duration of that impact, i.e., the time required for the populations to recover. The number of mole crabs on the beach at that time of the year of the spill is likely at a relative minimum and comprises mainly megalopae, juveniles, and males. In the unlikely event all of these were lost due to exposure to the oil, the overall temporal effect would be minimal. Research suggests that a large new set of megalopa recruit to the beach the following spring and will produce reproductively mature males and females by mid-summer. It is also likely that a reservoir of large females exists offshore and these will migrate back onto the beach in spring.

Moreover, using tagged specimens of *Emerita analoga*, Dillery and Knapp (1970) demonstrated that specimens of an average mole crab traveled about 15m/day in the direction of the prevailing currents on a beach at Isla Vista, California. They inferred from their study that aggregations of sand crabs are physically created and that a population observed in one location may move a considerable distance over a period of days This finding has relevance to both the occurrence of a sand crab exhibiting a match to COSCO BUSAN oil being found on a lightly oiled segment of Rodeo Beach adjacent to a heavily oiled portion of the beach and to the recovery of sand crab populations on beaches where sand crabs may have suffered mortality. Thus, it is likely that the sand crab populations should have recovered within several months even with an unlikely sudden total loss along segments of the shoreline.

The shimmy worm (*Nephtys californiensis*), is also a "broadcast" spawner with planktonic larvae. Consequently, if significant injury occurred, recovery would occur rapidly in the following spring without ongoing contamination.

If the exposed sandy beach assemblages were injured, the greatest potential injury would likely be to the organisms that brood their young, *i.e.,* the beach hoppers, isopods, and the opossum shrimp. Because these groups repopulate locally, the initial replacement populations would need to immigrate from other adjacent beaches. Depending on the life style of the species, the gravity of this problem varies. In the case of the opossum shrimp, which lives primarily in the water column, immigration and mixing of populations between beaches occurs rapidly as longshore currents carry seawater from beach to beach. In the case of the beach hoppers, they are not exposed to water-soluble hydrocarbons like other more aquatic organisms. They typically avoid contact with water, moving up and down the beach above the water line (Ricketts *et al.* 1985). Moreover, during the daytime and when the tide immerses their habitat, they bury up to 30 or more cm in the sand (Morris *et. al.* 1980). Consequently, their primary exposure to hydrocarbons would be by direct contact with tarballs. In view of the very low percent distribution of tarballs within the oiled band on lightly and very lightly oiled beaches, the percentage of beach hoppers that could potentially be exposed would be quite small. Even if populations were decimated on some beaches, it is likely they would recover within a year, based on normal dispersal, as long as the beach sediments were no longer contaminated. Typically, talitrid amphipods are reproductive from late spring until mid autumn and females produce two or more broods per season. Herkül *et al*. (2006) reported that a similar beach hopper species became widespread within a year following the initial introduction of a pioneering population onto a beach in the Baltic Sea.

The group that is likely most at risk are the cirolanid isopods, which live mostly in the sand in the mid-upper intertidal zone. Replacement populations for this taxon are derived from individuals moving from uninjured beaches. Such movements are a normal part of the behavior of this genus since its major food source appears to be dead sand crabs, *etc*. (Morris *et al.* 1980), and sand crabs exhibit great spatial and temporal variability. Ecological principles suggest that the predator *Excirolana* possesses similar dispersal capabilities in order to follow the prey. Moreover, because sand crabs are the greatest source of nutrition for these isopods, it is likely their abundance is low on these beaches during the winter or they are located offshore on the sand bars with the female sand crabs.

LIKELY CONCENTRATIONS OF PAH IN AMBIENT SEAWATER AND SEAWATER EXPOSED TO COSCO BUSAN BUNKER FUEL OIL

The average PAH concentration observed in seawater samples from the outer coast were determined to match COSCO BUSAN Bunker fuel oil was 1.373 ppb (n = 2; Table 2). The water-soluble fraction for PAH in seawater samples collected at reference sites in San Francisco Bay, ranging from 0.05 to 0.15 ppb (Payne *et al.* 2008), were generally somewhat lower than those published for the samples collected on the outer coast. Concentrations 0.7 miles offshore from Berkeley Marina, a site designated as heavily oiled for this event, were 0.05 ppb. Concentrations at control sites adjacent to a shoreline cleaning experiment at Berkeley Marina averaged 0.12 ppb. Finally, beside and inside the containment booms where shoreline cleaning and cleaners were being used, the concentration was 0.45 ppb.

Table 2. Concentration of water-soluble fraction of PAH in seawater samples collected on the outer coast following the COSCO BUSAN oil spill.

Type of Seawater	Average PAH Concentration
Outer coast seawater overall	0.737 ppb
Outer coast seawater samples with CB Match	1.373 ppb
Outer coast seawater samples with No Match	0.483 ppb

Generally, these concentrations are in line with those reported by Neff *et al.* (2000), who stated, based on analysis of extensive seawater samples from the EXXON VALDEZ oil spill, that, "Only 17% of water samples collected in spill-path areas contained more than 0.001 mg/L [ppm, or 1 ppb] total PAHs.

Likely WAF exposure concentrations can also be gathered from tissue body burden and bioconcentration BCF factors (BCF). BCFs for bivalves and PAH are listed in the table below (Table 3) from Neff (2002). Although estimated WAFs should be calculated for each individual PAH for each sample, we can get an idea of likely WAF using the median BCF of 3,180 to compare to average sample results.

The average bivalve tissue body burdens in lightly and very lightly oiled outer coast rocky beaches is 6,435 ug/Kg (median 2,504 ug/Kg) resulting in an expected exposure of less 1 ppb to less than 2ppb using a median PAH BCF value and assuming all of the tissue PAH originates from the CB oil (even though the analytical group has referred to the coastal mussel samples as a mix). The median value is used to remove the effects of outliers on shorelines with more oil than those in question. WAF should be estimated by looking at the BCFs for each individual PAH analyte and we recommend the analytical group weigh in on how much CB oil is in each sample and what the likely WAF would be.

For more relevant data to sand beaches we look at tissue body burdens following the spill in sand crabs that live in sandy beaches and find a range from 32 to 929 ppb. A total of 10 of 11 composite sand crab samples do not match the Cosco Busan oil signature (Table 4). The only sample listed as a probable match was collected in a light oiled area immediately adjacent to one of the most heavily oiled outer coast beaches (Rodeo Beach), an area where we do not have large disagreements with the Trustees in service loss and injury assumption DSAYs. All of the composite sand crab samples were collected in November and December of 2007. There are no matching tissue samples from burying infauna in very lightly oiled beaches and even those adjacent to heavily oiled beach samples show no exposure to most burying infauna. If more heavily oiled sites do not show exposure of sand-dwelling organisms to CB oil, we agree with the Trustees that it is not logical to conduct a study of toxicity or exposure at sandy beach sites with less oil.

Table 3. Equilibrium bioconcentration factors (CBFs) for selected PAHs in marine bivalve mollusk and fish tissues estimated with the log BCF/log Kow regressions of Pruell et al. (1987) and Veith and Kosian (1983), respectively.

Compound	Log Kow	Bivalve BCF	Fish BCF
Naphthalene	3.33	65	170
1-Methylnaphthalene	3.87	216	454
1,4-Dimethylnaphthalene	4.37	656	1,130
2,3-Dimethylnaphthalene	4.40	701	1,190
1,3,5-Trimethylnaphthalene	5.00	2,260	3,550
Fluorene	4.18	430	798
Phenanthrene	4.57	1,020	1,620
1-Methylphenanthrene	4.97	2,490	3,360
Dibenzothiophene	5.08	3,180	4,100
Pyrene	5.18	3,970	4,920
Fluoranthene	5.22	4,340	5,290
Chrysene	5.86	18,000	17,000
Benz(a)anthracene	5.91	20,100	18,600
Benzo(a)pyrene	6.04	26,800	23,500
Perylene	6.25	42,800	34,500
Indeno(1,2,3-cd)pyrene	7.00	226,000	135,000
Dibenz(a,h)anthracene	6.75	130,000	85,600
Coronene	6.75	130,000	85,600

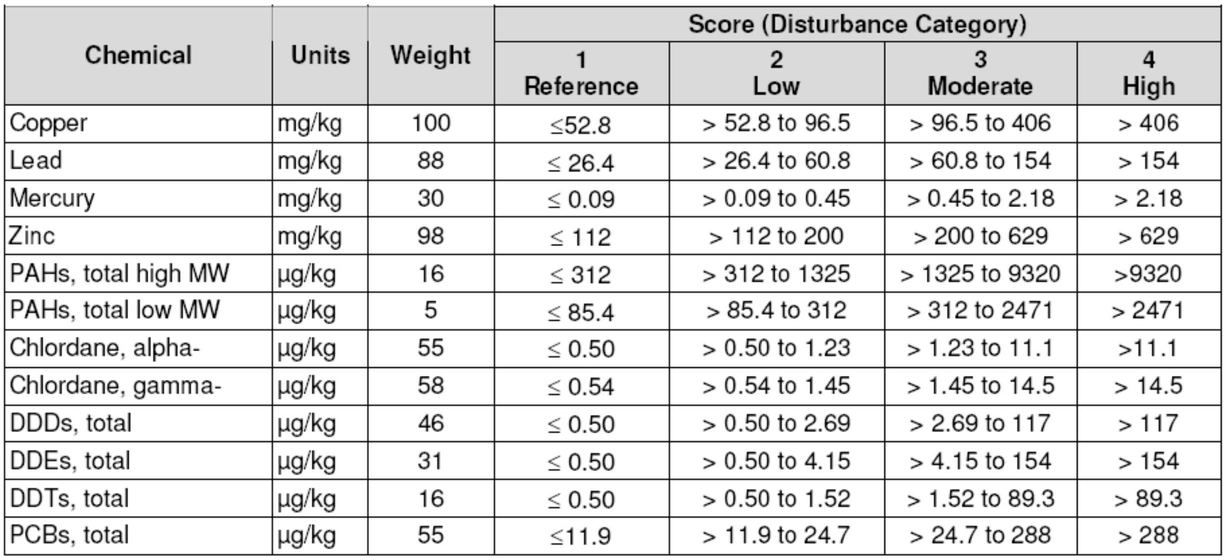
Table 4. Sand crab tissue analyses from outer coast sand beaches.

Match	Segment	Oiling Category	Sample ID	Date Collected	TPAH ug/Kg	Site Name	Species
NM	MRN04	H	MRN-SB-122007-01I	12/20/2007	48	Muir Beach	Mole Crab
NM	MRN04	H	MRN-SB-122007-02I	12/20/2007	65	Muir Beach	Mole Crab
NM	MRN04	H	MRN-SB-122007-03I	12/20/2007	59	Muir Beach	Mole Crab
PM Mix	MRO02	H	MR-O-F1-111907-01C	11/19/2007	929	Rodeo Beach	Mole Crab
NM	MRO02	??	MR-O-F1-122007-01Invert	12/20/2007	388	Rodeo Beach	Mole Crab
NM	SFJ02	VL	SF-J-SB-122207-1-I	12/22/2007	74	Ocean Beach	Mole Crab
NM	SFJ02	VL	SF-J-SB-122007-1-Invert	12/20/2007	47	Ocean Beach	Mole Crab
NM	SFJ02	VL	SF-J-FI-112007-01C	11/20/2007	74	Ocean Beach	Mole Crab
NM	SFJ02	VL	SF-J-FI-112007-02C	11/20/2007	68	Ocean Beach	Mole Crab
NM	SFJ02	VL	SF-J-FI-112007-03C	11/20/2007	32	Ocean Beach	Mole Crab
NM	SFH??	VL	SF-H-SB-122107-03C	12/21/07	2941	??Crissy Field	Mole Crab

The spill mass balance also suggests that the exposure on outer coast lightly and very lightly oiled beaches is very low when considering the extrapolated area that the oiled band is alleged to affect. For demonstration purposes, we assume no oil was recovered and all spilled oil is available to be stranded on the shorelines and cause injury. We partition the spill volume into the acres the trustees assume were exposed in each oiling category to estimate the gallons of oil per square meter in H, M, L, and VL sand beach habitats. For sand beaches, we assume that all the shoreline oil in the oiled band is spread across the entire beach evenly and not concentrated in the band for demonstration purposes although it is more typical for stranded oil at high tide to remain stranded in what is referred to as the strand line. The volume of oil spread across all the acres the Trustees assume were exposed and partitioned into H, M, L, and VL by looking at the degree of difference in each SCAT category results in less than 0.1 ml of whole stranded oil per meter squared on very lightly oiled beaches. Cosco Busan oil is 3.0% PAH (NOAA PAHs, Newfields, personal communication). Loose dry sand is 1,442 kg/cu.m (http://www.simetric.co.uk/si_materials.htm). If we assume the exposure only affects the top two centimeters of the sand beach, or 28.84 kg (1/50th of the cubic meter), this is equivalent to a sediment concentration of 3.25 mg/kg whole oil and approximately 0.098 mg/kg PAH, well below the average background sediment concentration in the bay and below levels reported to result in reference conditions in recently published sediment quality criteria for California Bays (Table 5)(State Water Control Board 2009).

The outer coast sediment samples analyzed include samples at Rodeo Beach, a segment with portions among the most heavily oiled of the outer coast beaches. Those results are mixed in terms of a CB oil match and the total PAH levels (62-626 ug/kg) fall within California reference and low disturbance sediment values for low and high molecular weight PAHs (Table 5). The sediment data in beaches with more than light and very light oiling also do not suggest community insult from toxicity.

Table 5. Category Score Concentration Ranges and Weighting Factors for the Chemical (Disturbance) Score Index (CA State Water Control Board 2009).



Chemical	Units	Weight	Score (Disturbance Category)			
			1 Reference	2 Low	3 Moderate	4 High
Copper	mg/kg	100	≤52.8	> 52.8 to 96.5	> 96.5 to 406	> 406
Lead	mg/kg	88	≤ 26.4	> 26.4 to 60.8	> 60.8 to 154	> 154
Mercury	mg/kg	30	≤ 0.09	> 0.09 to 0.45	> 0.45 to 2.18	> 2.18
Zinc	mg/kg	98	≤ 112	> 112 to 200	> 200 to 629	> 629
PAHs, total high MW	µg/kg	16	≤ 312	> 312 to 1325	> 1325 to 9320	>9320
PAHs, total low MW	µg/kg	5	≤ 85.4	> 85.4 to 312	> 312 to 2471	> 2471
Chlordane, alpha-	µg/kg	55	≤ 0.50	> 0.50 to 1.23	> 1.23 to 11.1	>11.1
Chlordane, gamma-	µg/kg	58	≤ 0.54	> 0.54 to 1.45	> 1.45 to 14.5	> 14.5
DDDs, total	µg/kg	46	≤ 0.50	> 0.50 to 2.69	> 2.69 to 117	> 117
DDEs, total	µg/kg	31	≤ 0.50	> 0.50 to 4.15	> 4.15 to 154	> 154
DDTs, total	µg/kg	16	≤ 0.50	> 0.50 to 1.52	> 1.52 to 89.3	> 89.3
PCBs, total	µg/kg	55	≤11.9	> 11.9 to 24.7	> 24.7 to 288	> 288

SENSITIVITY OF THE FAUNA ON EXPOSED SANDY BEACHES TO PAH

Given the above information, the notion of injury by the Water Accommodated Fraction (WAF) of the oil impinging on the exposed sandy beaches is not supported. If animals were exposed to CB WAF in lightly and very lightly oiled sand beaches, they were not likely exposed at levels that would result in measurable or observable injury. In the case of sand crabs, a study of the effect of weathered oil on megalopae of *Emerita analoga* reported that the No Effects Observed Concentration (NOEC) for both survival reduction (6-day) and growth limitation were 1.8 ppm Total Petroleum Hydrocarbons (TPH) as WAF, and the Lowest Observed Effects Concentration (LOEC) was 3.4 ppm TPH as WAF (Barron *et al.* 1999a).

In the case of the opossum shrimp, *Archaeomysis grebnitzkii* (or *A. maculata*), another important forage item that occupies the same level on the beach as the sand crab, the possibility of injury is probably slightly greater. When comparing the sensitivity of the sand crab to that of a standard bioassay test animal, the brackish water mysid (opossum shrimp) *Mysidopsis bahia*, Barron *et al.* (1999a) found that the opossum shrimp was somewhat more sensitive to oil in terms of mortality (2.9 times) and growth impairment (1.3 times). The NOECs and LOECs for the opossum shrimp, 0.91 and 1.8 ppm TPH as WAF (the same for survival and growth 6-day filtered 12-hour renewal seawater tests), were lower than those for the sand crab. (The mysid tests were run at a nominal salinity of 20 ppt versus 34 ppt for the sand crab tests). In a concurrent paper, Barron *et al*. (1999b) indicated that TPAH concentration for the LC_{50} for survival reduction in *Mysidopsis* was 7.8 ppb and the EC_{20} for growth inhibition was 5.7 ppb.

Regarding beach hoppers (family Talitridae), in a study of shorelines affected by the *Prestige* oil spill, which was nearly twice the size of the Exxon Valdez and more than 300 times larger than the Cosco Busan, Junoy *et al.* (2005), reported that: "*Species living in the upper level of the beach, as the talitrid amphipods Talitrus saltator and Talorchestia brito and the isopod Tylos europaeus were not significantly affected*" Since the massive oiling of many beaches in Galicia following the *Prestige* spill did not cause significant injury to beach hoppers, it is highly unlikely that the COSCO BUSAN spill caused measurable or observable injury in these types of organisms either on outer coast or in-bay sandy beaches in any level of oiling. High densities of beach hoppers were observed in the upper intertidal sand at Keil Cove within weeks following the spill (Dennis Lees, personal observation).

It is also unlikely that cirolanid isopods on outer coast sand beaches were injured by exposure to PAH from the COSCO BUSAN oil spill. In reporting on chronic sublethal effects of the water-soluble fraction of No. 2 fuel oils, Lee (1978) found that adult specimens of *Sphaeroma quadridentatum*, an isopod similar to cirolanid isopods such as *Excirolana* spp., grew and reproduced at WSF concentrations of No. 2 fuel oil exceeding 2 ppm but that populations exposed to concentrations above 0.2 ppm (>200 ppb WSF, which includes monocyclic hydrocarbons)"may eventually disappear" over several generations (one month exposure tests at >15% WSF). However, the concentrations reported by Lee (1978) are two or more orders of magnitude higher than was observed in seawater samples collected following the COSCO BUSAN oil spill.

We agree with the Trustees that WAF or sediment toxicity is not likely the avenue of injury to burying infauna and consider physical contact and fouling to be a potential injury vector. We offer further comments herein on the conceptual approach to study contact effects discussed among the group on October 30, 2009 under Study Comments below.

MUD AND SAND FLATS

The fauna of the mud and sand flats differ dramatically in several respects. The benthic infauna of the mud flats is quite impoverished (Lees, personal observation), comprises primarily introduced or invasive species, dominated by ephemeral, or "weed" species, and is representative of a largely disturbed habitat (Cohen and Carlton 1995). Major points listed in the Executive Summary of this report include:

1. The San Francisco Bay and Delta region is a highly invaded ecosystem.
2. A vast amount of energy now passes through and is utilized by the nonindigenous biota of the estuary. In the 1990s, introduced species dominate many of the estuary's food webs.
3. Introduced species may be causing profound structural changes to some of the estuary's habitats.

In contrast, the fauna observed on the sand beaches and flats is dominated by larger, longer-lived species, particularly a ghost shrimp (*Neotrypaea [=Callianassa] californiensis*), and the small, obligate commensal clam *Cryptomya concentrica*. These species, both abundant in the sandy sediments, are both native to the west coast of the U. S., and are common in protected sandy sediments throughout California.

Compared to well-developed mud flats such as Morro Bay, biomass of the megainfauna on mud flats around San Francisco is low (Brusati and Grosholz 2006). Cursory visual surveys on several mud flats in the bay reveal an extreme paucity of: 1) burrows that indicate larger burrowing organisms characteristic of better developed mud flats, *e.g.*, burrowing mud and ghost shrimp, large, long-lived clams and large worms; 2) shell material of larger clams; 3) middens of crushed clam shells left by diving ducks when they feed on abundant clams such as *Macoma petalum* (=*M. balthica*).

Papers by Nichols and Thompson (1985) and Brusati and Grosholtz (2006) provide insights into the types and species of organisms that dominate the infauna of the mud flats in San Francisco Bay. Nichols and Thompson (1985) indicate that the mud flat assemblage in South San Francisco Bay comprised primarily by "introduced species with opportunistic lifestyles, is dominated numerically by [the small clam] *Gemma gemma*, *Ampelisca abdita* [a gammarid amphipod], and [a small polychaete worm] *Streblospio benedicti*. These species, and most of the other species reported in this paper, generally live less than one year and respond rapidly to the chronic disturbances that affect the mud flats. These species are abundant at upper, mid, and lower intertidal areas, and most other common species also occur across the entire tide range.

Nichols and Thompson (1985) noted that "The total number of species in… the San Francisco Bay mud flats is lower than that found in the equivalent community of the eastern United States", attributing this to a "smaller pool of potential colonizers", its geologic youth, isolation from other estuaries, and the "textural uniformity" of the sediments. They apparently were not aware of the diversity and richness of the mud flat assemblages in Elkhorn Slough and Morro Bay, to the south and estuaries in Oregon, Washington, and Alaska to the north.

Two sites studied by Brusati and Grosholtz (2006) were in central San Francisco Bay (San Lorenzo and Alameda) and the third site was in San Pablo Bay. The infauna reported was relatively similar to that described by Nichols and Thompson (1985) and so it appears to be safe to assume that the infauna found on other mud flats in San Francisco Bay is similar. Brusati and Grosholtz (2006) reported dry tissue weights for infauna on these mud flats ranging from <5 g/sq. m to over 70 g/ sq. m for an approximate average of 31 g/sq. m. This compares poorly with an estimated average for dry tissue weight of ≈320 g/sq. m from mud flats in Cook Inlet, Alaska (Lees *et al*. 1978).

Generally, the sensitivity of mud flat assemblages appears to be relatively low. Christie and Berge (1995) found that recolonization of oiled sediments by meiofauna was generally unaffected at 100 to 250 ppm but definitely was reduced at 400 ppm. Macrofauna appeared to tolerate sediment concentrations of PAH up to 600 ppm and concentrations above 1000 ppm reduced densities of most species. After applying 1 liter of fuel oil per square meter of sediment inoculated with mud-flat macrofauna in mud-flat simulators with wave action, Chung *et al*. (2004) reported that the macrobenthos had recovered to pre-spill densities after about one month. They suggested that the macrofaunal response is closely related to the degree that seawater infiltration is affected by the oil. In the case of the mud flats in San Francisco, because of the apparent paucity of large burrowing organisms, sediments do not appear to be very porous and seawater infiltration is low.

Based on these studies, it is unlikely that the concentrations of hydrocarbons flowing across or residing upon the mud flats in San Francisco Bay could have caused a significant effect. First, the sediment collected to demonstrate exposure were classified as No Match in lightly oiled shorelines, although they had substantial pyrogenic background sources. Second, the PAH concentrations in these sediments were far below those identified as causing effects. The average value for TPAH in sediments collected for this spill was 1.3 ± 1.02 ppm (n = 22), the maximum was 5.36 ppm and the minimum was 0.05 ppm. A sediment sample collected at the Yerba Buena Mussel Watch site in 2006 contained 8.0 ppm.

It is unlikely the ghost shrimp and the clam inhabiting the sand beaches were affected significantly by the hydrocarbons associated with the COSCO BUSAN oil spill. Because they burrow deeply in the sediments, they are primarily exposed only to the water-soluble fractions in the water column. They could be exposed to small particulates of the oil that develop as the oil weathers. The ghost shrimp feeds on the sand in which it burrows and so the particulates would need to be entrained deeply in the sediment column before ingestion could be an exposure pathway. The commensal clam is a suspension feeder in the water that the shrimp circulates to oxygenate the burrow. However, water is only circulated when the entrances to the burrow are inundated by the tide. Based on measurements by Payne (2008), the concentration of the water-soluble fraction appears to be far below concentrations that would cause mortality or long-term injury to either of these species.

The average pre-spill (October 2007) bivalve tissue sample from the Bay analyzed as part of this assessment is 3,322 ppb (Range - 814-11,428 ppb, Median - 2,481 ppb, Standard Deviation - 3,706 ppb). The analytical group also has access to many other background samples. If we look at all sand flat sample results (Table 6) including those adjacent to moderately oiled beaches, we can estimate a conservative COSCO BUSAN contribution to the tissue body burden. Only 5 of 8 samples are above pre-spill October 2007 background sample averages. The range of above-background deviation in the 5 samples is 810 to 9,017 ppb. The WAF exposure responsible for the highest observed concentration would be 2.7 ppb using the median BCF for PAHs in bivalves from Neff (2002). The average deviation from background of the tide flat tissue samples (Table 6) that are above background is 2,696 ppb, corresponding to a WAF exposure of less than 1 ppb (WAF) using the BCF assumptions discussed. If we look at only the adjacent flats to light and very light oiled shorelines, we estimate exposure that would result in the average deviation from the body burden of 0.7 ppb WAF. The only sample collected offshore on the tide flats and some distance from the oiled shoreline has a tissue body burden lower than pre-spill and non-matching samples (301 ppb) and suggests it is not a certain conclusion that the offshore tide flats must have been adversely affected. We believe the best way to estimate the exposure level is to start with the estimated PAH level of CB contribution from the analytical group.

There are several other ways for the group to explore exposure by examining non-matching tissue samples during the spill as reference or by having the analytical group provide a range of percent contribution of CB oil in matching samples from heavy, moderate, light, and very lightly oiled shorelines.

Table 6. Sample results from mud flat bivalves at shoreline edge.

NF	PECI	Date	Location	Species	TPAH	Sample	Degree Oiling
PM	M	12/11/2007	Bolinas	Cryptomya	4,132	MRM-SM2-121107-1CC	Very Light
PM	M	12/19/2007	Brooks Island	Cryptomya	6,980	CCZ-SM2-12192007-3-CC	Light
PM	M	12/19/2007	Brooks Island	Cryptomya	10,339	CCZ-SM2-12192007-1-CC	Light
Match	M	1/30/2008	Brooks Island	Cryptomya	12,339	CCZ-SM2-01302008-3-CC	Moderate
I	PM	3/25/2008	Brooks Island	Cryptomya	1,627	CCZ-SM1-032508-CC1	Moderate
PM	PM	1/31/2008	Brooks Island	Cryptomya	9,322	CCZ-SM1-013108-CC1	Light
PM	PM	12/19/2007	Keller Beach	Cryptomya	2,987	CCY-SM3-121907-1-CC	Very Light
PM	PM	12/20/2007	Emeryville Crescent	Cryptomya	🟩 301	ALA-122007-SM1-CL1	Light

🟩 Sampled collected offshore

We can also partition the spilled oil volume into the acres the trustees assume were exposed in each oiling category as with outer coast beaches in order to estimate the gallons of oil per square meter in H, M, L, and VL habitats in the flats. For adjacent habitats, we assume that all the shoreline oil is spread across the adjacent habitats and not stranded on the shoreline for demonstration purposes. If we assume the exposure only affects the top one centimeter of the mud or sand flat, or 14.42 kg (1/100th of the cubic meter), this is equivalent to a sediment concentration of 6.5 mg/kg whole oil and approximately 0.19 mg/kg PAH, an order of magnitude lower than the average sediment concentration in the Bay and within levels reported to result in reference conditions in recently published sediment quality criteria for California Bays (State Water Control Board 2009). Since the oil consisted largely of tarballs, these concentrations would not exist in > 99% of the area without tarballs. It is very likely that, like the sandy outer coast shorelines, toxicity was also not a potential avenue of injury as suggested by these data.

STUDY COMMENTS - PRELIMINARY COMMENTS ON INITIAL TOXICITY/PHYSICAL FOULING STUDY PLANS BEING DEVELOPED BY THE TRUSTEES

Toxicity Studies using *Mytilus*

The Trustee proposal attempts to infer a habitat service loss in an adjacent nearshore tidal flat using a non-tidal flat test organism (mussel). The test physiological endpoints have no known ways of translating to a habitat service loss, let alone a service loss on an adjacent dissimilar habitat. We are concerned the study may not meet the objective of the desire to conduct the study, which was to reduce the technical differences regarding service loss in adjacent tidal flats and provide more certainty to an injury determination. We recognize there are substantial challenges to studying PAH effects of exposure at very low levels and in locations with substantial levels of background contamination. We offer the following preliminary comments in order to refine our understanding of how the study results may be used:

- As mentioned, we have concerns about the appropriateness of the test animal. We appreciate that they are a readily available source of test organism and have been studied extensively. However, mussels do not occur naturally on sand or mud [or, alternatively, tidal flats] and most of the spill-related samples were collected on the shoreline and not the adjacent offshore sand or mud flats. How will we make inferences regarding the habitat service of a sand or mud flat based on physiological changes in a mussel that was collected on a shoreline that may be substantial distances from the sand or mud flat in question?
- We continue to have concerns regarding the distance from shore of many of the sand or mud flats where the Trustees assume injury and believe the *Cryptomya* tissue samples demonstrate a relationship between PAH concentration and distance from shore . It is not appropriate to use an average mussel tissue PAH body burden from the lightly and very lightly oiled shoreline to infer the offshore exposure on the large area of tidal flats.
- Assumed exposure for tidal flat bivalves may not be equivalent to the estimation of deviation from average background tissue PAH. Most sand flat *Cryptomya* samples are probable matches to Cosco Busan. A tissue sample of 10 or 12 ppm PAH, if it were 8 or more ppm above background, would be a clear analytical match and not a possible match. We recommend that the analytical group consider the exposure of the tidal flat *Cryptomya* to

provide input as to the likely body burdens and WAFs that result from Cosco Busan Oil on tidal flat samples.

- A determination of average background concentration for bivalves should include only the bay bivalve samples if the majority of all inferences are directed at bay injury. Drakes Bay samples likely reduce the estimated average background concentration of most areas about which we are attempting to make inferences and should be removed from the estimation of average background concentration. The reduction of the estimate of average background concentration will result in an overestimation of CB exposure. Mussels used for PAH analysis should be depurated in order to allow examination of actual hydrocarbon concentrations. In the tissues.
- Determining mud/sand flat habitat service loss is the goal of the study. While the conceptual approach has value to science in terms of understanding PAH-associated physiological changes that may occur in mussels, we do not believe it currently addresses the objective of the tidal flat service loss assessment. The study cannot answer the question of the magnitude of habitat service loss. For example, the group has not considered how a change in lysosomal destabilization, scope for growth, or other effects will translate to the mud flat habitat service loss. We recommend the group reach an agreement on how habitat service loss will be inferred from the metrics being studied prior to moving forward. We cannot recommend moving forward with a study until we understand how the results may be translated to our objective, habitat service loss and duration.
- The Trustees propose to study all exposure categories (H, M, L,VL). The Trustees assume 100% and 60% service loss in Moderate and Heavily oiled shorelines. For settlement purposes, the RP has not challenged those assumptions, although we believe they overstate the loss. Will the Trustees reduce the loss in these categories if the tests do not suggest that there would be 100% and/or 60% service loss (mortality) in the heavily and moderately oiled exposure tests?

Conceptual Approach to Study Fouling by Oil on Outer Coast Sand Beaches

The Trustees have suggested the injury to sand beach organisms on the outer coast is physical fouling and/or contact toxicity by tarballs. They have indicated they are considering a two-pronged approach of studying whole oil contact injury by conducting an oil contact study with beach organisms and a separate desktop exercise to estimate tarball movement and how many organisms it may come into contact with during the course of movement. We believe the second part of this assessment should be considered prior to moving forward.

We offer the following example for illustrative purposes and use the data from the spill for lightly and very lightly oiled outer coast beaches. SCAT data for the oiled bands on the outer coast are used to estimate an average of 1.8% oil distribution on 1.22 acres (length X width) for lightly oiled sand beaches and 1.0% distribution on 3.18 acres of very lightly oiled beaches (<1% is assumed to be 0.5%). We understand that some beaches may not have been observed in their worst oiling condition. However, since the Trustees postulate the oil is constantly moving, then SCAT teams must also have documented the same oil on different beach segments on different days and oil cannot be causing contact/fouling damage in more than one place at the same time. Therefore, the assumptions above represent an objective, reasonable and conservative average estimate.

Lightly Oiled Sand Beaches:

SCAT data indicate 1.22 acres (4046.87 sq meters/ac) X 1.8% average oil distribution, or 88 square meters of oil as tarballs on all lightly oiled outer coast sand beaches.

The Trustees assume that the exposure above resulted in a 40% service loss to 595,700 square meters of sand beach (147.2 acres). From a habitat perspective, if we assume the loss of a percent of habitat is equivalent to the loss of a percent of service, each tarball would have to adversely affect and cause the loss of service to an area that is nearly 2,700 times the combined area of the tarballs (595,670 sq m/88 sq m of tarballs X 40%).

Probable physical contact with some of the more common organisms may also be examined. Mole crab density is reported for Ocean Beach by a student monitoring program (Dean et al. 2007) to vary between as low as ≈10/sq m to as many as >700/sq m in summer months with a declining trend from 700/sq m to 10 /sq m over the 4 year study period (2003-2006). Assuming the low density of 10/sq m in the swash zone for November 2007, and assuming the swash zone is only one third of the beach area, there would be nearly 2 million mole crabs in the lightly oiled beach segments (<u>595,700 sq m</u> X <u>1/3 swash zone</u> X <u>10 crabs/sq/m</u>). Conservatively assuming that 1/3 of all stranded tarballs remain in the swash zone to cause contact injury, this would equate to 29.3 square meters of the estimated total 88 square meters of oil. Using an average radius of 1.7 cm per tarball or 1,000 tarballs per square meter of oil (29,300 tarballs in the swash zone below the 1.22 acre oiled band in the 147 acre lightly oiled shorelines), each tarball would have to contact and adversely affect nearly 30 mole crabs to achieve physical contact with 40% of the population. Using a high density estimate of mole crabs each tarball would have to contact over 2,000 mole crabs to affect 40% of the population. If that occurred, it is not plausible that nearly all composite samples of mole crab tissues on all beaches did not match Cosco Busan oil since many mole crabs are contained in each composite sample.

The Habitat Group discussed the possibility of either rapid depuration or initial mortality as the reason for only one matching sample out of 11 composite samples of mole crab tissue. If complete depuration in only several weeks explains why the analytical analyses could not detect a Cosco Busan signature, then we question the injury assessment of 40% and 20% service loss to the habitat for lengthy time periods. Conversely, the assumption of initial contact mortality in the days following the spill and then no exposure in mid November through December 2007 during the sampling period does not make sense in light of ongoing tarball observations on the shoreline throughout the mole crab sampling period.

The above example also conservatively assumes 40% beach service loss as assumed by the Trustees is inferred by a 40% contact rate of tarballs and burying infaunal organisms. We do not believe that a simple 40% contact rate equals 40% habitat service loss, but for the sake of discussion let us assume all contact equals mortality since the levels of biota contact required to result in a 40% habitat service loss for the period assumed by the trustees cannot occur with the very small percentage of oil available. A tarball can also only contact so many things before it is no longer a tarball, or contact no longer results in exposure due to weathering of the oil and specifically adsorption onto inorganic particulate material on an active sand beach. We find it very unlikely that every tarball finds multiple organisms to harm.

Very Lightly Oiled Sand Beaches:

SCAT data indicate 3.18 acres (4046.87 sq meters/ac) X 1.0% average oil distribution, or 128.7 square meters of oil as tarballs on all very lightly oiled outer coast sand beaches. To estimate the average tarball concentration, less than 1% is treated as 0.5%, although less than 1% is often reported as trace and can be far less than 0.5% distribution. A single tarball on some beaches resulted in large segments being classified as very lightly oiled. In these instances, the single tarball would have to contact thousands of organisms to affect a significant portion of the interstitial population.

The Trustees assume that the exposure resulted in a 20% service loss to 1,860,752 square meters of sand beach (459.8 acres). From a habitat perspective, if we assume the loss of a percent of habitat is equivalent to the loss of a percent of service, each tarball would have to adversely affect and cause the loss of service to an area that is over 2,800 times the area of the tarball (1,860,752 sq m/128.7 sq m of tarballs X 20%).

We use the same estimated mole crab density as above of 10/sq m in the swash zone for November 2007 to estimate probable physical contact in very lightly oiled sand beaches. Assuming the swash zone is only one third of the beach area, there would be nearly 6.2 million mole crabs in the very lightly oiled sand beaches (1,860,752 sq m X 1/3 swash zone X 10 crabs/sq/m). Assuming tarballs are distributed across the entire beach, there would be 42.9 square meters of tarballs in the swash zone at any one time if the swash zone is 1/3 of the beach cross section (128.7 sq meters of tarballs X 1/3 of beach). Assuming 1,000 tarballs per square meter of oil (average radius of approximately 1.7 cm), or 42,900 tarballs in the swash zone below the 3.18 acres of oiled band, each tarball would have to contact and adversely affect nearly 30 mole crabs to achieve physical contact with 20% of the population. If that were probable, it is not likely that nearly all composite samples of mole crab tissues on all beaches in the month following the spill did not match Cosco Busan oil. The fouling loss of over a million mole crabs in the initial days following the spill should have been observable to shoreline observers. In beaches where the Trustees assume 100% service loss, there should have been millions of dead mole crabs in the wrack and in the swash zone.

Both scenarios above conservatively assume the 20% and 40% contact rate of organisms is a surrogate for beach service loss assumptions of 20% and 40%. We do not believe that contact equals habitat service loss, but for the sake of discussion we may avoid a physical contact study and assume all contact equals mortality to demonstrate the overstatement of the potential injury by the Trustees on lightly and very lightly oiled sand beaches. In addition, the density of all burying infaunal organisms is much higher than that of mole crabs; hence each tarball would have to contact and adversely affect many hundreds or thousands of organisms to affect a meaningful proportion of the overall population that justifies the high community service loss rates anticipated by the Trustees.

We are willing to discuss the possibility that every tarball contacts an organism to foul, which results in the loss of a very small percentage of the population, which is likely why population or community effects have not been reported in studies of low levels of oiling in Santa Barbara, California (Allen,and Schlueter 1970, Galloway 1992, State Lands Commission 1978, Straughan 1982). Furthermore, many of the species living buried in the sand do not come to the surface, i.e., enter the water column, where they could come into contact with tar balls.

SUMMARY

In summary, the biological and toxicological characteristics of the fauna living on exposed sandy beaches that may have been exposed to COSCO BUSAN oil provide a strong basis for concluding that injury due to exposure to the oil was negligible in severity and short in duration. Sand crabs, the largest of the beach-dwelling species, are present in low numbers during the winter and most of the sand crabs present are males. The males are basically annuals and megalopae or very young sand crabs. If these populations are injured, they are rapidly replaced in the spring when large numbers of megalopae surge onto the beach from outside sources, develop rapidly, and become reproductive by early to mid-summer. Most importantly, there is no CB tissue body burden in 10 of 11 sand crab samples collected on or near heavily oiled shorelines in November and December 2007 following the spill. It is not logical to study the potential toxicity of CB oil to sand-dwelling organisms from shorelines that would have been less exposed than sediments classified as "unexposed" or reference by the State Water Resources Board (2009).

The sand crab and opossum shrimp that live in the swash zone immigrate into injured areas rapidly from adjacent uninjured areas because they are moved by longshore currents and swim well. Isopods of the genus *Excirolana* are likely sparse in the winter because of the paucity of their primary food source, sand crabs. Considering the spatial and temporal nature of their food source, they are likely able to recolonize an injured area rapidly when (if?) their food supply returns in the spring. Beach hoppers on the upper beach typically do not come into contact with the seawater that would contain dissolved PAHs that are generally associated with toxicity. The primary exposure pathway would be contact with the tarballs. Considering the overall paucity of tarballs on the outer coast beaches, very few beach hoppers would come in contact with tarballs.

Available toxicity data for sand crabs, mysids, and isopods, in combination with the data on TPAH in seawater samples from outer coast sites, suggest that concentrations of PAHs in the seawater is substantially lower than the NOECs or LOECs for these animals or analogous species. The literature supports that the WAF was insufficient to cause measurable or observable toxic effects. In fact, the empirical data for sand crabs indicate little or no exposure to any WAF even in more heavily oiled locations.

While the RP remains committed to our original agreement with the trustees of a simplified approach that relies on literature studies and available data, the literature studies we provided in the Spring of 2009 that looked at ecological communities in southern California in response to frequent natural crude oil seeps (Allen and Schlueter 1970, Galloway 1992, State Lands Commission 1978, Straughan 1982) and in this report suggest no measurable ecological effect. The empirical data from sand beaches suggests no exposure to WAF by burying infaunal organisms on more heavily oiled beaches. Any model of toxicological effects and service loss should be supported by evidence of exposure and/or injury. The life histories of the organisms assumed injured should be considered and the on-site tissue data should corroborate exposure. Even if we assume the empirical data from the site and the studies of California beaches in Santa Barbara are incorrect, the volume of oil spilled during the COSCO BUSAN spill is insufficient to deliver a meaningful dose to the number of square meters of lesser oiled shorelines the trustees assume were exposed.

The empirical evidence does not support the assumption of organism exposure and/or injury on lightly and very lightly oiled sand beaches on the outer coast. The only composite sample of clams collected offshore on a tide flat within the bay is among the lowest of observed tPAH body burdens from a bivalve in the bay before or after the spill. Even tissue samples collected at lower elevations but within close proximity to the oiled band (*Cryptomya, Venerupis,* and *oysters*) exhibited substantially lower concentrations of PAH than those collected from higher elevations (*Geukensia* and *Mytilus*). Even if we assume the tidal flat tissue samples collected in close proximity to oiled shorelines were representative of tidal flats several hundred meters from the oiled band, the body burdens are low and not substantially different than pre-spill samples. The associated doses in a toxicity test would be exceedingly low given the BCF in bivalves and considering the worst case scenario water column data from the most severally affected areas during shoreline oil releasing agent application and flushing. The RP is willing to consider service losses within the oiled band itself as stated previously. The RP is also willing to consider additional analysis of any un-analyzed samples that may provide further clarifying information.

In summary, we offer the following main concerns specific to lightly and very lightly oiled sand beaches and adjacent mud flats:

- The tissue body burdens of interstitial sand beach organisms collected in November and December and 2007 show no evidence of exposure.
- Sediment samples in more heavily oiled beaches were below California sediment reference levels.
- The nature and life histories of sand beach organisms is such that injury duration, if it occurred, would not persist for the duration assumed by the Trustees
- The volume of oil spilled is not sufficient to provide doses that could result in toxicity across the acres assumed exposed by the Trustees.
- There remains no documentation or evidence that all acres of tidal flats in the Bay were exposed to CB Oil, and the only existing empirical data suggests extremely low exposure offshore.
- Tissue body burdens of samples collected in the bay on tide flats immediately adjacent to the oiled shorelines are low and bivalve BCF values suggest any WAF exposure was limited
- The only tissue sample collected on a tidal flat offshore from the oiled shoreline has a tPAH value well below the average non-matching sample and well below any reported levels that result in changes in scope for growth or lysosome activity.
- The proposed toxicity study does not yet present a way forward to estimate habitat service loss based on the proposed test organism and metrics being studied.
- The conceptual contact toxicity study as a desktop exercise demonstrates the low likelihood of the Trustees service loss assumptions.
- The trustee assumptions of service loss would have resulted in substantial mortality and are not supported by any observations.

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