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Subcommittee on Water, Oceans, and Wildlife

Hearing Title: DDT Dumping Off the Southern California Coast: Ecological Impacts, Scientific Needs, and Next Steps

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Mr. Chairman and Members of the Subcommittee:

Thank you for the opportunity to speak before you today about DDT dumping off the southern California coast and its ecological impacts, scientific needs, and next steps.

I am a Professor and the Division Head of Environmental Health in the School of Public Health at San Diego State University. My research is focused on (1) the fate of organic contaminants in global and microscopic environments, including biota; (2) the identification of previously unrecognized and novel contaminants; and (3) human and wildlife contaminant exposure assessments. I have 20 years of experience in the analysis of trace levels of chemical contaminants in various sample matrices utilizing chromatography and mass spectrometry to understand the contaminants' behavior in various environmental media. This includes the use of targeted and non-targeted mass spectrometry methods for environmental contaminant monitoring. Since I joined San Diego State University in 2009, ocean and human health in southern California has been one of my primary research interests. Research projects include the investigation of persistent organic pollutants and novel contaminants' impacts on the ecosystem. One of the consistent findings across multiple projects was DDT and DDT-related chemicals were the most abundant environmental contaminants in marine mammals with habitats that include southern California.

Brief History of Dichlorodiphenyltrichloroethane (DDT) in southern California[1]

DDT was widely used to control insects on agricultural crops and insects that carry diseases beginning in the 1940s. A textbook published in 1962 for environmental scientists, Rachel Carson's *Silent Spring*, warned of the inadvertent toxicity of DDT to other wildlife. In 1972, the US EPA banned DDT based on its adverse environmental impacts including eggshell thinning in birds, which affects reproduction success, and its potential as human carcinogen. Montrose Chemical, located in the Los Angeles region, was the largest producer of DDT in the US from 1947 to 1982. Until the 1970s, the company disposed of tons of technical DDT and associated waste products through the local sewer system, which was connected to the municipal wastewater treatment plant at White Point on the coast of the Palos Verdes Peninsula. The chemical waste was then discharged a few kilometers into the ocean by the treatment plant's outfall system. This heavily contaminated the Palos Verdes Shelf (the seabed off the coast) with DDT and other chemicals, and generally this sediment was considered the single primary source

of DDT to regional wildlife. Although, as discussed below, this may not be the case due to DDT dumping further offshore.

1. Centers for Disease Control and Prevention, US Environmental Protection Agency, and US Fish and Wildlife Services

Why does DDT still matter in southern California?

It has been almost 50 years since the ban on DDT. Why is DDT regionally important? Here, we use the term DDT to encompass both the specific chemical dichlorodiphenyltrichloroethane and DDT-related compounds. DDT has the following characteristics. (1) "Persistent," which means it resistant to degradation and can presently be detected in the environment, wildlife, and humans. Furthermore, the primary degradation product, *p,p*'-DDE, is itself also persistent and exhibits reproductive toxicity in wildlife. (2) "Lipophilic," meaning DDT is fat-soluble and partitions to sediment from water, where DDT to enters food chain and accumulates in the fatty tissues of organisms. (3) "Semi-volatile," meaning it can also be transported in the atmosphere. Importantly, DDT biomagnifies through food chains, meaning predator species accumulate higher body burdens of DDT than their prey species, resulting in high contaminant accumulation at the top of the food web. Top predators such as marine mammals have the highest wildlife concentrations, making them vulnerable to toxic contaminants and as sentinels for marine contamination and more broadly ocean and human health. Finally, DDT pollution is still regionally important because the true extent and exact chemical makeup of the of the original contamination is not well understood. Therefore, the long-term fate (e.g., time to natural removal) and risk to the environment is unclear.

Our recent measurements of DDT accumulation in Southern California marine mammals

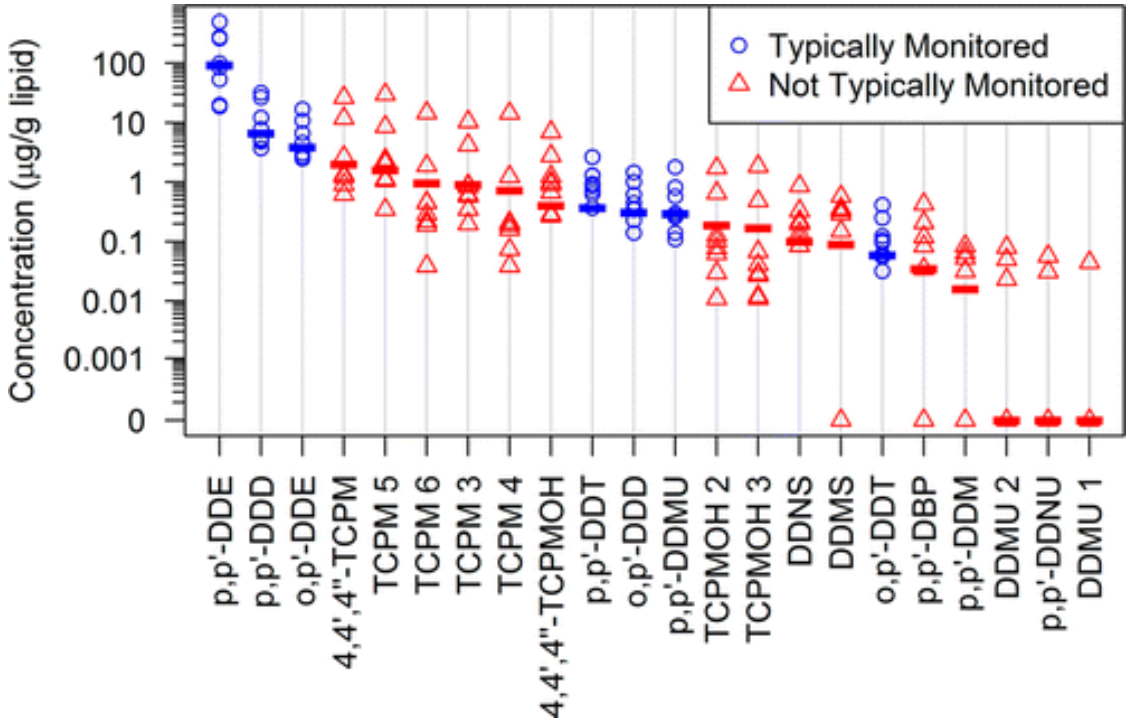
We analyzed blubber samples from eight mature common bottlenose dolphins (*Tursiops truncatus*) that inhabit near-shore or deeper off-shore regions of the southern California coast (Mackintosh et al. 2016). All dolphins were fatally stranded on beaches in the region between 1995 and 2010. This was a follow-up of our previous work (Shaul et al. 2015). In the first study, a broad contaminant survey, we found DDT was the most abundant contaminant class among 25 classes observed in the dolphin blubber. In the follow-up investigation, we specifically examined DDT and DDT-related compounds for their identities (chemical structures), potential sources, and blubber concentrations.

Two important findings are relevant to the current concern regarding DDT pollution in the southern California marine environment and the newly discovered DDT waste barrels. Please note again, here the term DDT does not refer a single chemical, but a mixture of related chemicals. In most surveys of environmental DDT pollution, 4 to 8 specific chemicals related to DDT are measured. Our investigation examined the occurrence of these and other DDT-related chemicals.

First, the DDT blubber concentration of the southern California bottlenose dolphins was the highest among regions of the US and globally where data was available. This is a comparison among blubber from the same dolphin species, adult male dolphins only, and a collection period between 1995 and 2015. On average, the $\sum_4$DDT concentration was 178 µg/g lipid and the

$\sum_6$DDT concentration was 184 µg/g lipid and (n=8) for the blubber samples quantified in this study. $\sum_4$DDT is the sum of four DDT compounds (*p,p'*-DDT/DDD/DDE and *o,p'*-DDT) and $\sum_6$DDT is the sum of six DDT compounds (*p,p'*- and *o,p'*-DDT/DDD/DDE). $\sum_4$DDT and $\sum_6$DDT are common reporting conventions in the scientific literature. These concentrations are an order of magnitude higher than bottlenose dolphin values reported elsewhere (see Table S4 in Mackintosh et al., 2016).

Second, we identified 45 DDT-related compounds for the first time in bottlenose dolphin blubber, including the major DDT chemicals, DDT transformation products, DDT technical mixture impurities such as tris(chlorophenyl)methane (TCPM), the presumed TCPM metabolite tris(chlorophenyl)methanol (TCPM-OH), and structurally related compounds with unknown sources, such as hexa- to octa-chlorinated diphenylethene. Evidence suggested that environmental transformation may have contributed to most of the load of observed DDT-related compounds (i.e., many of these DDT-related compounds were not present at high levels in the original technical DDT mixture, but were likely formed through environmental degradation). TCPM and TCPM-OH, identified for the first time in southern California marine mammals, were present in technical grade DDT as impurities at very low concentrations. But their concentrations were abundant in the bottlenose dolphins, suggesting high biomagnification potential (4,4',4"-TCPM was ranked 4th in concentration among individual chemicals, see the graph below which is Figure 5 in Mackintosh et al., 2016). As a class of structurally similar chemicals, TCPM-related compounds were the second most abundant compound class measured in the blubber. Theoretical estimates corroborated that 4,4',4''-TCPM and 4,4'4,"-TCPM-OH are persistent and bioaccumulative. The DDT waste in dumped barrels may have also contributed to the high TCMP load (discussed below).



We observed similar results in 22 blubber biopsies collected from live male bottlenose dolphins collected from 2012 to 2016 in southern California (Trego et al., 2019). In this study, *p,p'*-DDE (a major DDT breakdown product) was the most abundant individual contaminant and 4,4',4''-TCPM was second, among 25 representative persistent organic pollutants (Figure 1 in Trego et al., 2019). On average, $\sum_3$ DDT, the sum of *p,p'*-DDT/DDD/DDE, was 130 µg/g lipid and 4,4',4''-TCPM was 42 µg/g lipid, which were substantially higher than for the commonly studied and abundant PCB and PBDE contaminants (Table S1 in Trego et al., 2019).

A survey of additional southern California marine mammal species including long-beaked common dolphin, Risso's dolphin, short-beaked common dolphin, Pacific harbor seal, and California sea lion collected from 1990 to 2014, observed the same trend. DDT and DDT-related compounds including TCPM were the most abundant contaminants measured in marine mammal blubber (Cossaboon et al., 2019). Together, this research demonstrates marine mammals with habitats in southern California are exposed to high levels of DDT-related contaminants relative to other regions. Presumably, the source of these chemicals is the historical DDT discharge onto the Palos Verdes Shelf and the DDT barrel dumping further offshore. The habitat ranges of these marine mammals extend beyond southern California, but the high abundance of TCPM in the blubber is an indicator that the DDT load is acquired in this region (see below).

Recently Observed Adverse Effects of DDT in California

We measured a large suite of more than 300 halogenated organic compounds and the hormone testosterone in blubber from 16 southern California male short-beaked common dolphins (*Delphinus delphis*). We found 11 contaminant classes were negatively correlated with blubber testosterone, including DDT/DDT-related compounds, TCPM, and TCPMOH. Evidence suggested that the elevated DDT and TCPM load contributes to impaired testosterone production in *D. delphis* males (Trego et al., 2018).

We also examined the impact of halogenated organic contaminant exposure on cellular physiology in free range male southern California bottlenose dolphins (*Tursiops truncatus*). We quantified 25 representative halogenated organic compounds including DDT and TCPM in the blubber of 22 biopsies collected between 2012 and 2016, and analyzed genome-wide gene expression in the skin and observed correlations between halogenated organic compound levels and gene co-expression networks enriched for xenobiotic metabolism, hormone metabolism, and immune response. This may indicate negative cellular impacts from halogenated organic compounds including DDT and TCPM (Trego et al., 2019).

Other research groups reported recent environmental impacts of DDT along the California coast. Gulland et al. 2020 published a large wildlife population study, "Persistent contaminants and herpesvirus OtHV1 are positively associated with cancer in wild California sea lions" (Gulland et al., 2020). The prevalence of cancer in wild California sea lions (*Zalophus califonianus*) is serious, with 18-23% of adult animals examined post-mortem over the past 40 years having urogenital carcinoma. This study surveyed 394 animals collected over 20 years for cancer occurrence, viral OtHV-1 infection, exposure to persistent organic pollutants (i.e., halogenated organic contaminants such as DDT, PCB, PBDEs, and chlorinated pesticides). The study

discovered that the odds of carcinoma occurrence was 44 times higher in sea lions infected with OtHV-1, and 1.5 times higher for every tripling of contaminant concentrations in their blubber, after controlling for the effects of blubber depth. Thus, two factors, viral infection and contaminant exposure, were linked to cancer in the California sea lions.

According to Kurle et al. 2016, California condors (an endangered species) that inhabit the California coast had a larger body burden of persistent organic contaminants (12 to100 fold greater) than those of noncoastal condors. The mean blood plasma DDE (a major metabolite/breakdown product of DDT) concentration for coastal condors was 500 ± 679 ng/g wet weight (mean ± standard deviation, n=22) versus 24 ± 24 ng/g wet weight (n=8) for noncoastal condors. Coastal condors' primary diet source is dead stranded marine mammals, which as discussed above have high concentrations of the same contaminants. The study estimated that approximately 40% of breeding-age coastal California condors have DDE levels associated with eggshell thinning in other avian species. Reproductive problems observed in California condors reintroduced to coastal sites (i.e., eggshell thinning, depressed hatching success, endocrine disruption) is associated with an increased DDT body burden through the scavenging of marine mammal carcasses (Burnett et al. 2013, Felton et al. 2015).

Urgent issues regarding the offshore DDT waste barrels

In 2011-2013, Dr. Valentine's research team surveyed and sampled a dumpsite offshore of California and discovered that discarded waste containers littered the site, which sits below 3000 feet of ocean water (Kivenson et al., 2019). They found sediment at that site was contaminated with DDT at levels 40 times greater than on the nearby Palos Verdes Shelf (the location of the discharge from the White Point wastewater treatment plant). The chemical composition and estimated mass balance of DDT and PCB in the site sediment suggested that the offshore DDT waste barrels might be major source of DDT pollution in the region, and that the long-term assumption that the Palos Verdes Shelf is the primary source of DDT pollution in the region is incorrect. In addition, TCPM and TCPMOH were also present in the dumpsite sediment, suggesting these chemicals could be more abundant in DDT waste generated during manufacture than in the DDT technical mixture. Thus, our observation of high body burdens of TCPM and TCPMOH in southern California marine mammals can be connected to the offshore DDT waste barrels. Following up on the barrel discovery, a very recent survey by the Scripps Institution of Oceanography, in partnership with NOAA, revealed the presence of >27,000 dumped barrels extending across a broad section of the ocean floor. Historical records and observation of the barrels indicate they were brought out by ship and sometimes punctured to ensure they would sink.

The DDT in the deep ocean barrel dumping sites, with relatively low oxygen and sunlight, is likely more persistent than on the shallower Palos Verdes Shelf. DDT pollution is sometimes considered "past" or "done". However, with the discovery of the DDT waste barrel dumping and the scientific questions it poses, this issue is unresolved, and the scientific investigation is just starting. Currently, regional wildlife is exposed to high levels of DDT, DDT degradation products, and impurities such as TCPM and TCPMOH. The associated ecotoxicological impacts threaten ocean and human health in the region. It is critically important to reassess DDT

pollution in the southern California marine environment and more broadly, along the western coast of the US, since potentially impacted wildlife can have large habitats. Unknown questions regarding the offshore DDT waste barrels include: 1) What is the full spatial extent of the barrel dumping, condition of the leaks, and estimate of the total DDT waste mass? 2) What is the full chemical makeup of the contamination? The chemicals may have varying biological impacts. 3) To what extent are the barrels contributing to the DDT observed in local wildlife and outside southern California? 4) What is the risk posed by the abundant but non-traditional DDT compounds? 5) Can the long-term fate of DDT in the marine sediment be predicted? 6) Humans are part of the marine food web. Are any populations at elevated risk? The work required to answer such questions is complicated and challenging but urgent. We believe that a multidisciplinary research team with 21st century technology is essential for the investigation. Dr. Aluwihare's statement proposes our approach and strategies.

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