A DEEP OCEAN DDT+ RESEARCH NEEDS ASSESSMENT *for the* SOUTHERN CALIFORNIA BIGHT

January 2023

Sea Grant
University of Southern California

Sea Grant
California

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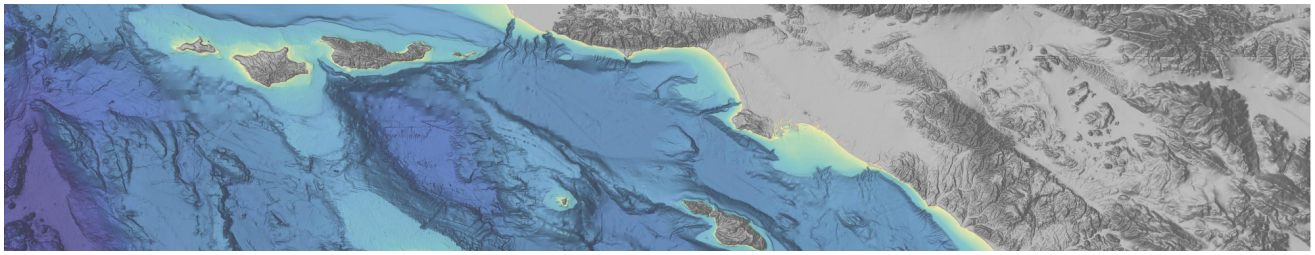

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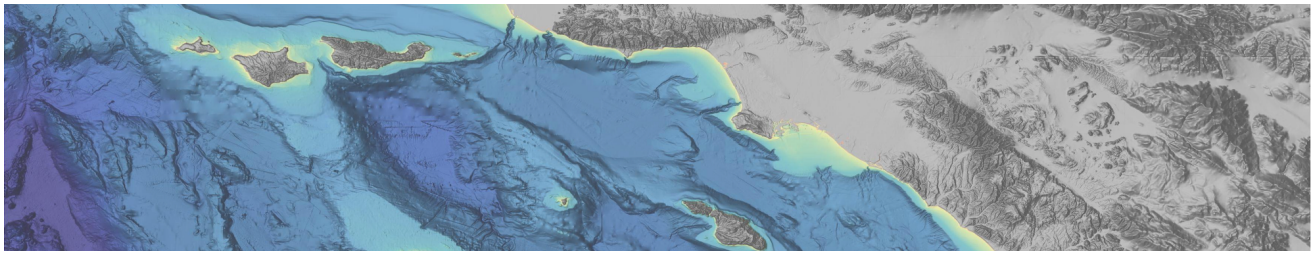
PREFACE



When the University of Southern California and California Sea Grant Programs learned of the broad extent of DDT+ (i.e., DDT and associated compounds and byproducts) deposits in the San Pedro and Santa Monica Basins, the immediate concern was how to help address this issue. Both programs participated in early discussions on the topic and consulted with colleagues at the California Ocean Protection Council. There was a clear need to investigate what research is needed to determine the extent of the Southern California DDT+ problem and the potential effects on marine ecosystems and human health.

The issue of deep ocean DDT+ contamination is not going to be solved soon or by any single entity. That's what brought our Sea Grant Programs together to undertake a California DDT+ Research Needs Assessment based on the knowledge and concerns held by technical and community experts. Leveraging the convening of DDT+ technical experts at the California Coastal Chloro Contamination Conference in May 2022 at the University of California Santa Barbara, our programs hosted a follow-up California DDT+ Research Needs Workshop in July 2022 and Community Listening Sessions in November 2022. This was a collaborative, community effort in the truest sense. Participants among varying professions and interests convened to address the questions: what are the highest priority research questions, and how can research dollars be best invested going forward?

Please note that what ultimately should or should not be done with the deep ocean DDT+ in the Southern California Bight was outside the scope of this Assessment. Instead, the Assessment focused on what research is needed *most urgently* and what research questions could be answered *quickly* with a *large impact* on subsequent research and decisions moving forward. **This is a time for action, but informed action.** Both Sea Grant Programs led this Assessment to help assist decision-makers to take the next steps forward in a timely, productive, and impactful way.

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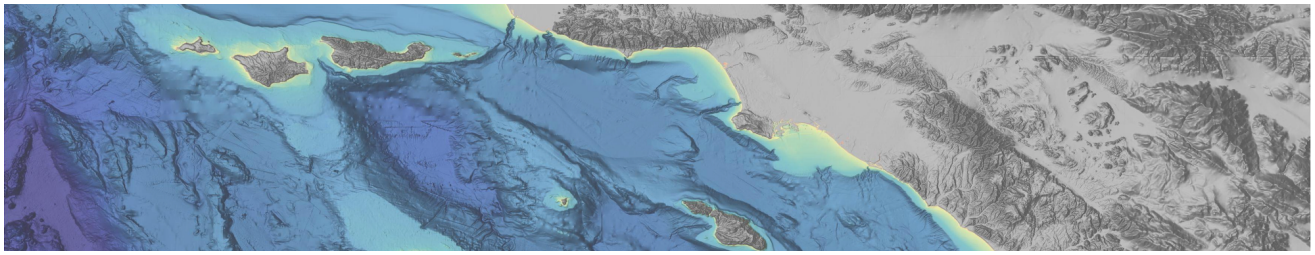
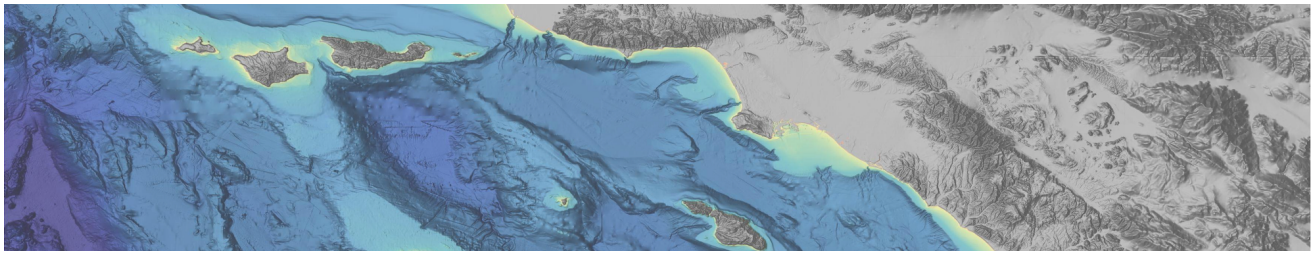


GLOSSARY



Anoxia: A condition of no oxygen in a water body or sediment, which can occur naturally (as in deep ocean settings) or due to human activity (referred to colloquially as a dead zone). Also see related term, *hypoxia*.

Bioaccumulation: The process by which a substance, such as pesticides or other chemicals, can accumulate in a single organism over time. It occurs when the substance is absorbed faster than the body can get rid of it, ultimately causing toxic effects. For example, DDT is known to accumulate in fat tissue across marine mammals.

Bioavailability: The extent to which a chemical substance becomes absorbed and biologically available for exposure to a living organism, which can lead to adverse physiological effects or toxicity.

Biomagnification: The process by which the concentration of a chemical increases through the food web, with the highest amounts occurring in higher level predators. Predators with high fat concentrations like marine mammals can be particularly susceptible to DDT biomagnification.

Bulk-dumping: The action of dumping large volumes of non-containerized waste originating from a manufacturing facility directly into the ocean.

C5: The California Coastal Chloro Contamination Conference (C5) was held at the University of California Santa Barbara in May 2022 (Appendix B). Organized by Dr. David Valentine, the conference was influential in helping Sea Grant generate a draft list of research needs to begin broader discussion at the July 2022 Workshop.

DDT: Dichlorodiphenyltrichloroethane (shortened to "DDT") was a widespread insecticide used from the 1940s until its nationwide ban in 1972 due to its harmful impacts on wildlife and probable carcinogenic effects on humans.

DDT+: Scientists now understand that there is a much broader suite of DDT breakdown products, potentially more than 45 compounds and related byproducts (collectively referred to as "DDT+"), that can have toxic effects but have not been traditionally monitored in the environment.

Effort vs. Impact: In the context of this Assessment, Impact was defined by what degree a research need could inform management or decision-making, and/or those that would influence or enable other areas of research. The Effort required to complete research was defined as funding, time, or personnel required.

EPA, Region 9: The United States Environmental Protection Agency "Region 9" implements and enforces federal environmental laws in Arizona, California, Hawaii, Nevada, the Pacific Islands, and 148 tribal nations.

GLOSSARY (CONT.)

Hypoxia: A condition of low or depleted oxygen in a water body or sediment, which is typically harmful for oxygen-dependent organisms. Also see related term, *anoxia*.

Montrose: The Montrose Chemical Corporation of California was a chemical manufacturer operating near Torrance, CA and was the largest U.S. producer of the insecticide DDT from 1947 until 1982. In 2000, Montrose and three other parties settled lawsuits with the federal government and the State of California for a collective $140 million for natural resource damages resulting from DDT+ discharges to the Palos Verdes Shelf.

Palos Verdes Shelf: An area of approximately nine miles long and up to 300 feet in water depth off the Palos Verdes peninsula; contained within EPA's Montrose Superfund site due to DDT and PCB contamination.

PCBs: Polychlorinated biphenyls is a class of manmade chemicals that was manufactured in the U.S. from 1929 until it was banned in 1979 due to a variety of toxicity effects for wildlife and humans.

Pore water: Water contained in the (interstitial) spaces between individual grains in a sediment.

Superfund site: In this report, the Superfund site mentioned refers to the "Palos Verdes Shelf Operable Unit of the Montrose Chemical Corp. Superfund Site." It includes acreage on land where the Montrose Plant and other chemical plants were located, as well as other surrounding locations, including DDT and PCB contaminated sediment off the coast of the Palos Verdes peninsula near Los Angeles (a 17-square mile area).

Remediation: The action of reversing or repairing environmental damage, such as through removing pollutants from the sediment or water supply. In the context of DDT in Southern California, several remediation efforts on land and along the nearshore shelf have been conducted; however, no remediation has occurred to date in the deep sea contamination sites.

Short-dumping: Disposal DDT+ waste from ships prior to reaching the offshore locations designated for legal disposal in 1940-1960s.

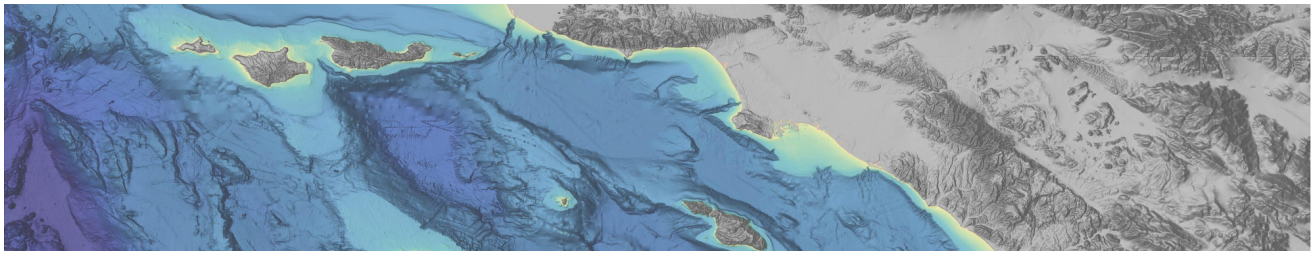
Southern California Bight: A 430-mile stretch of curved coastline and ocean that runs from Point Conception in Santa Barbara County, CA down to Punta Colonet in Baja California, including the Channel Islands.

Tar Cakes: There is evidence that much of the DDT+ disposal off the coast of California was not contained in barrels; some may have been disposed in mixtures of other chemicals as well as with petroleum sludge. These petroleum chemicals can form tar residue, such as tar cakes.

TCPM, TCPM-OH: Tris(4-chlorophenyl)methane (shortened to TCPM) and tris(4-chlorophenyl)methanol (shortened to TCPM-OH) are two DDT+ related, persistent, and bioaccumulative chemicals. TCPM is believed to be an impurity generated during the manufacturing process of producing the insecticide DDT, and TCPMOH to be produced from TCPM in the environment. Relatively recently, these compounds were found in both physical and biological samples where DDT+ was analyzed.

Workshop: Abbreviation in this report to refer to Sea Grant's July 2022 California DDT+ Research Needs Workshop.

EXECUTIVE SUMMARY



DDT (Dichlorodiphenyltrichloroethane) may be an old pollutant, but recent scientific findings and media focus have reignited concern about deep ocean DDT contamination in the San Pedro and Santa Monica Basins. This region contains highly productive ecosystems that fall outside of the U.S. Environmental Protection Agency Montrose Superfund site along the Palos Verde Shelf. New studies have illuminated a broad suite of DDT breakdown products and related byproducts (more than 45 compounds collectively referred to as "DDT+") that can have toxic effects but have not traditionally been monitored in the environment.

The critical gaps in our knowledge about the nature, extent, fate, and impacts of deep ocean DDT+ pollution have instigated calls from communities and researchers as well as U.S. congressional and California state leadership for considerable research investment. In response, the University of Southern California and California Sea Grant Programs (herein collectively referred to as "Sea Grant"), with funding from the National Sea Grant Office, conducted *A Deep Ocean DDT+ Research Needs Assessment for the Southern California Bight* (hereafter referred to as the "Assessment") in 2022 to generate a comprehensive list of DDT+ research needs as well as provide context on what research is most critically needed. Sea Grant aims for this Assessment to provide a framework for a deep ocean DDT+ research agenda to inform future California DDT research investments.

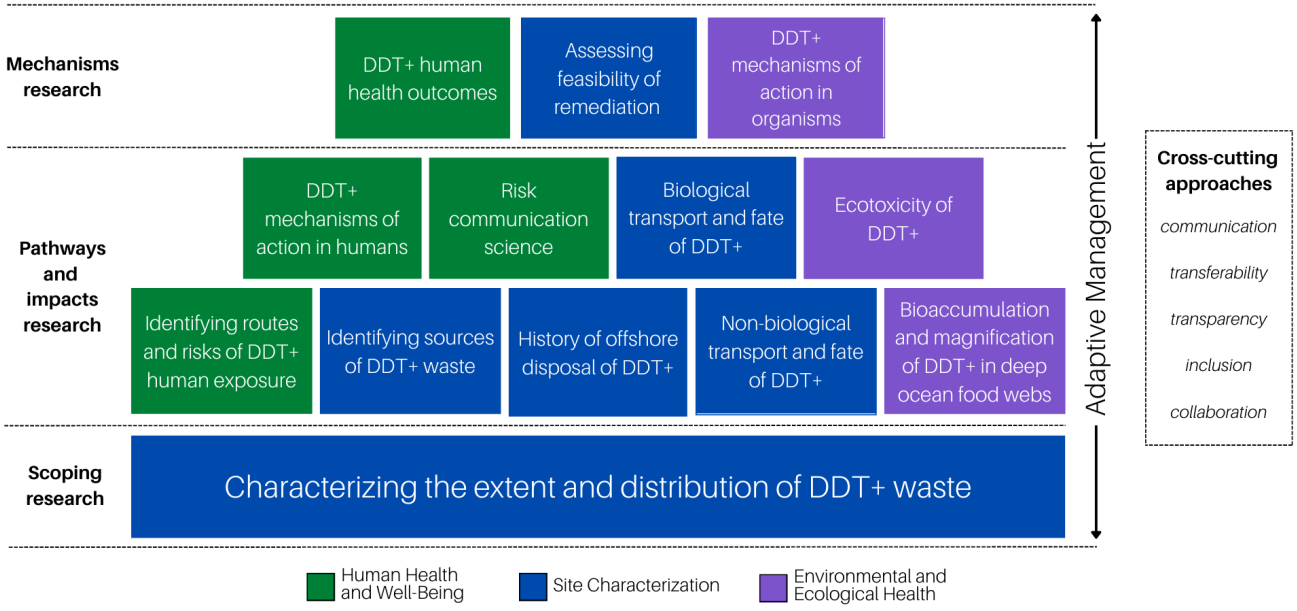
A primary source of input for this Assessment was Sea Grant's California DDT+ Research Needs Workshop (July 18-19, 2022) which convened diverse communities managing, studying, or directly affected by deep ocean DDT+ disposal in the Southern California Bight. Participants contributed to the development of a comprehensive list of DDT+ research needs across three themes (i.e., **Site Characterization**; **Environmental and Ecological Health**; **Human Health and Well-Being**).

Sea Grant aims for this Assessment to provide a framework for a deep ocean DDT+ research agenda to inform future California DDT research investments.

The workshop was followed by virtual Community Listening Sessions in November 2022 with DDT+ technical experts, interested community members, and tribal representatives who were either unable to attend the July Workshop or were interested in providing further input on a draft of the Assessment report.

Based on Workshop and Community Listening Session discussions, Sea Grant organized research needs through an adaptive model (see schematic below) that illustrates how research categories (i.e., groups of related research needs) relate and could iteratively build on one another to efficiently increase overall understanding and impact. Research categories, which are depicted lower in the model, should provide the basis for research scope (e.g., research sites, chemical congeners examined, species tested, etc.) for research categories higher in the model. Researchers should *adapt* their approaches and questions as more information is learned at lower levels of the model.

Assessment participants echoed that cross-cutting approaches (e.g., communication, transferability, transparency, inclusion, and collaboration) would be crucial to building a highly impactful and effective research agenda.



Adaptive model of deep ocean DDT+ research needs in the Southern California Bight.

What Sea Grant heard from the diverse participants engaged in our Assessment was that the ultimate goal of any research objective should be to contribute toward mitigating the risk of DDT+ exposure to human and marine life. To do this, the first step is to understand what kind of DDT+ waste is currently there, where it currently is, and its potential for harm. Therefore, characterization of the extent and distribution of DDT+ in the deep ocean serves as the foundational research area in which to invest immediately that subsequently will inform and support all other management-relevant research needs. Examination of DDT+ in present-day sediments, pore water, water column, and deep ocean food web will provide a snapshot of where DDT+ hotspots are located, what chemicals or mixtures are present, and potential pathways of exposure to be investigated.

Across all themes, four research needs consistently emerged as ***priorities***:

- **Investing funding early** in the characterization of the extent of DDT+ in deep ocean sediments will provide direction and management context to all other compiled human and ecosystem health research needs.
- There is still much to learn about the toxicity of the 45+ DDT-related compounds on local marine and coastal organisms; examining the **combined or synergistic effects** of co-occurring environmental stressors on DDT+ toxicity is challenging but essential to understanding the holistic impact of DDT+ within the marine environment.

...the ultimate goal of any research objective should be to contribute toward mitigating risk of DDT+ exposure to human and marine life.

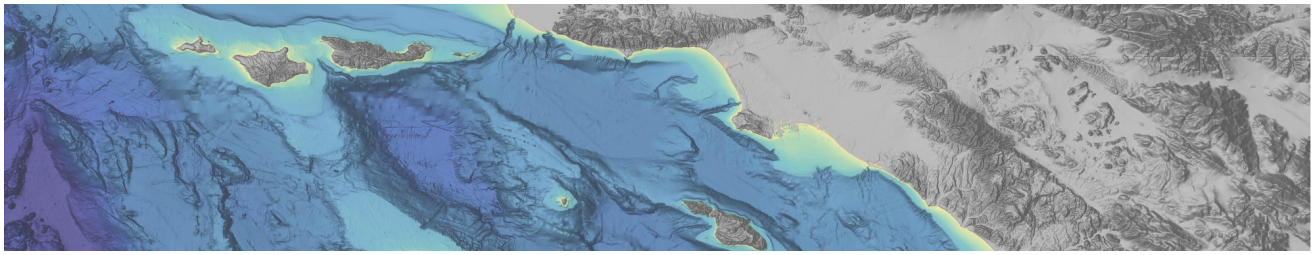
- Limited available resources will require leveraging existing information to pursue the **research necessary to mitigate risk**, particularly for vulnerable human populations, even while research examining routes of exposure and impacts is still underway.
- Examination of best practices to **communicate the actual risks** of deep ocean DDT+ exposure and dispel inaccurate assumptions will be integral to communicating specific exposure risks to different user groups.

Sea Grant also heard requests for ***immediate actions*** that would enable leveraging past research efforts and strengthen coordination of future ones. These Immediate Actions could be considered for additional funding considerations in the near future. These include:

- Completing a **data needs assessment**
- Creating a **living catalog** of archived samples and DDT+ research programs
- **Standardizing** research protocols and consideration of transferability of methods and techniques
- Creating a DDT+ **governance framework**
- Fostering a collaborative California Deep Ocean DDT+ **Community of Practice**
- Fostering ongoing **risk communication**
- Fostering better **inclusion** and **transparency**

Overall, despite Southern California's complicated history with DDT+, this Assessment highlights the opportunity for spearheading a new chapter driven by exceptionally collaborative, innovative, and efficient deep ocean DDT+ research.

INTRODUCTION



A Brief History of DDT+ and Deep Ocean Disposal in Southern California

DDT in Southern California

Southern California has a complicated history with DDT, a widely used insecticide from the 1940s until it was banned in 1972 due to its harmful impacts on wildlife and potential carcinogenic effects on humans. The largest DDT producer in the United States, Montrose Chemical Corporation, operated in Torrance, California. The waste products resulting from this operation were discharged via the Los Angeles County wastewater treatment plant to the Palos Verdes Shelf, or transported (in barrels or as sludge) and dumped illegally en route to and in legally "designated" disposal sites off the coast [1].

The collective release, discharge, and disposal of DDT+ wastes has led to legacy contamination in several aquatic and marine ecosystems off Southern California. During the 1990s, a federal Natural Resource Damage Assessment (NRDA), led by the National Oceanic and Atmospheric Administration (NOAA) as well as other federal and state natural resource trustees, resulted in a settlement with Montrose and other parties for $140.2 million. This action focused on the effects to the shallow, subtidal, marine environment of the Palos Verdes Shelf from the Los Angeles County Sanitary Districts' wastewater treatment plant. This nearshore contamination also led the U.S. Environmental Protection Agency (EPA) to designate a 17-square-mile area within the Palos Verdes Shelf as a DDT Superfund site, which is still undergoing periodic monitoring today.

What is New and Why the Deep Ocean Disposal Sites Matter

Though offshore disposal of DDT in Southern California has been documented by scientists since the 1980s [1, 2], new scientific understanding as well as recent media focus [3] have ignited broader concern about DDT contamination in the deep waters of the San Pedro and Santa Monica Basins, areas falling outside the Montrose Superfund site. This ecosystem is highly productive, containing essential fish habitats, two marine protected areas (Point Vicente and Abalone Cove State Marine Conservation Areas), a vibrant coastal tourism industry, a nascent aquaculture industry, and established fishing communities (recreational, subsistence, and commercial).

New scientific information has fostered growing attention to the impacts of deep ocean disposal of DDT+ in the Southern California Bight. The scientific community has discovered a much broader suite of DDT breakdown products and related byproducts (collectively referred to as "DDT+") in marine mammals [1] and deep ocean sediments [4] than was previously understood or monitored during the Palos Verdes NRDA process.

As described further in the three subsections of *Findings* below (i.e., **Site Characterization**; **Environmental and Ecological Impacts**; **Human Health and Well-Being**), growing understanding of the vast geographic extent of DDT+ disposal sites, as well as the primary method in which DDT+ was disposed (i.e., 'bulk dumping'), has raised new concerns about the potential risk to ecosystem and human health.

The two confirmed deep ocean DDT+ disposal sites shown in Figure 1 below, often referred to as Disposal Sites #1 and #2, are approximately 10 miles from the Palos Verdes Shelf. Disposal Site #1 encompasses multiple slopes in the Santa Monica Basin and thus contains a mix of depths. In contrast, Disposal Site #2 is located at the deepest extent of the San Pedro Basin (~900 meters) and is relatively flat. These topographic characteristics may drive differences in the transport and fate of DDT+ by biological and non-biological mechanisms, as well as pose unique challenges to investigate each site. These two sites are the primary focus of the Sea Grant Assessment. Federal investigations to date have focused on Disposal Site #2, the location where Scripps Institution of Oceanography conducted a preliminary survey in early 2021 [5].

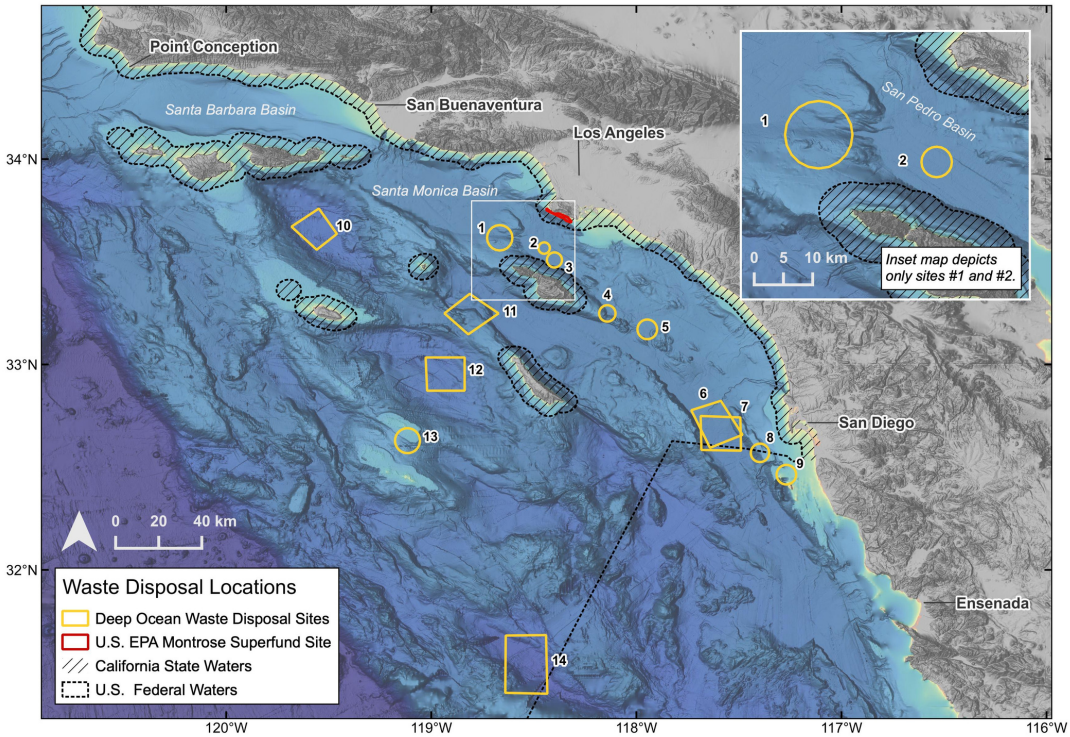


Figure 1. *Approximate location of 14 known deep ocean disposal sites off Southern California [6]. Disposal Sites #1 and #2 are confirmed DDT disposal sites [1]. The established U.S. EPA Superfund site near Palos Verdes, California, is also depicted (solid red line) (Map credit: K. Alvarez, USC Sea Grant)*

For a detailed history of DDT and research to date in Southern California, please refer to Chartrand et al, 2022 [1] and the EPA Region 9's "Southern California Ocean Disposal Site #2 Investigation" website [5].

Timing and Purpose of a Research Needs Assessment

The critical gaps in our understanding of the transport, fate, and impacts of deep ocean DDT+ pollution on marine ecosystems, seafood safety, and human health have caused growing concern among citizens, researchers, and California policymakers. In November 2021, congressional representatives requested that the Department of Health and Human Services and the EPA investigate the human health impacts of DDT+ contaminated seafood in Southern California [7]. Scientists also testified before Congress in June 2021 communicating the critical need for research funds to identify the full scope of the Southern California DDT+ ocean disposal sites, impacts of the magnitude of DDT+ on marine ecosystems and humans, and methods of remediating the DDT+ sites [8]. Federal and state entities have responded; the federal government appropriated $5.6 million for studies on the San Pedro Basin DDT+ disposal site, an amount which the State of California intends to match in spending on DDT+ initiatives between 2023 and 2025 [9-11].

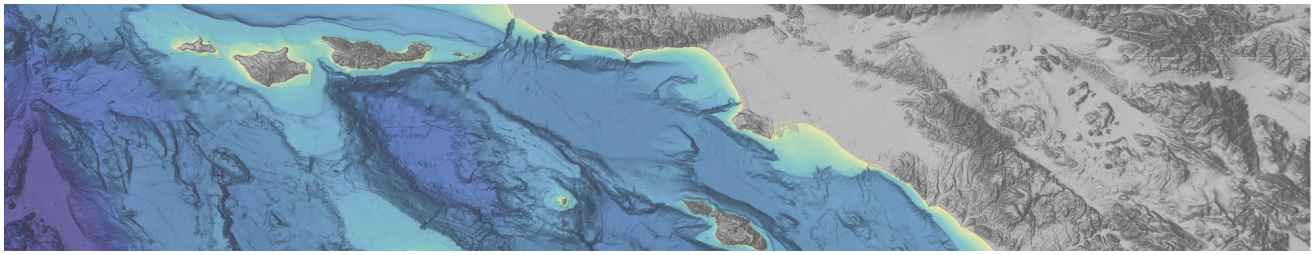
...it was clear that Sea Grant could fill a critical leadership role by facilitating more inclusive discussions between the academic community and various local, regional, and state entities to identify and articulate the dimensions of DDT+ research needs.

The NOAA Science Council convened early conversations in 2021 among DDT researchers in the California region to discuss leveraging existing intellectual and financial capital to fill research gaps.

In those early convenings and subsequent conversations with California Ocean Protection Council leadership, it was clear that Sea Grant could fill a critical leadership role by facilitating more inclusive discussions between the academic community and various local, regional, and state entities to identify and articulate the dimensions of DDT+ research needs.

In the fall of 2021, the University of Southern California and California Sea Grant Programs (herein collectively referred to as "Sea Grant") received rapid response funds from the National Sea Grant Office to facilitate an urgently needed research agenda that informs potential funders interested in investing in deep ocean DDT+ impacts in Southern California. Sea Grant coordinated the California DDT+ Research Needs Workshop (herein referred to as the "Workshop") on July 18-19, 2022, and gathered additional input through Community Listening Sessions, in order to develop this Assessment as a critical tool to navigate the complex scope of DDT+ research needs identified by technical experts and communities impacted by deep ocean DDT+ waste.

OUR ASSESSMENT APPROACH



We gathered diverse perspectives from those communities managing, studying, or directly affected by the DDT+ deep ocean disposal in the Southern California Bight to understand priority DDT+ research needs for this region. Below we describe our approach to gain scientific and community-based sources of knowledge via a literature review, convenings of technical experts and interested parties, and Community Listening Sessions.

Literature Review

To develop a preliminary draft of research needs for deep ocean DDT+ in the Southern California Bight, we completed a scoping review of recent scientific literature (see *References* section), public testimony (e.g., [8]), and government reports (e.g., [5]) to identify research gaps. The comprehensive 2022 report, "Updating and Reviewing Research on Continuing Ecological Effects of Deepwater Ocean Dumping of DDT Wastes into the Southern California Bight" [1], and the extensive citations therein served as a critical resource.

From the research gaps identified by the literature review and in consultation with our Workshop Advisory Committee (see Appendix A), Sea Grant developed a draft list of research needs essential to assessing the extent and impacts of offshore DDT+ waste disposal in the Southern California Bight. Sea Grant provided this draft list to attendees prior to the Workshop and used it as a starting point for Workshop discussions.

California Coastal Chloro Contamination Conference (C5)

On May 16-17, 2022, Dr. David Valentine organized and convened the California Coastal Chloro Contamination Conference (C5) at the University of California, Santa Barbara. This two-day workshop was intended as a community-building exercise for scientists and other community members interested in any aspects of DDT+ and other offshore disposal along the California Coast. Sea Grant staff attended the C5 Conference, compiling research updates and knowledge gaps throughout the meeting. The Agenda and List of Speakers from the C5 conference can be found in Appendix B.

C5 attendees participated in a 1.5 hour group activity to discuss the most critical information needed to chart a path forward in response to impacts of offshore waste disposal of DDT+ in the Southern California Bight. In collaboration with the C5 attendees and organizers, Sea Grant integrated the outputs of the brainstormed discussion into the draft list of research needs for broader discussion in Sea Grant's July 2022 Workshop.

Workshop Goals, Attendees, and Structure

Sea Grant's two-day, interactive Workshop supported four broad goals:

- Convene an inclusive, collaborative discussion among Sea Grant, academic scientists, and diverse California communities;
- Share context of the history of DDT contamination in Southern California and potential implications for human and environmental health;
- Synthesize those DDT impacts of greatest concern to diverse communities, building on the groundwork of previous scientific assessments of California DDT research needs;
- Provide continued opportunities for engagement in the development of this Assessment.

Attendees

The goal of this Workshop was to move beyond information sharing on the state of the science and convene diverse communities for forward-looking discussions of research needs and strategies to accomplish this necessary research. As a result, the outreach and invitation list for the Workshop was intentionally broad and diverse. The Workshop was attended by 80 individuals on the first day and 70 individuals on the second day. They represented academia, research, policy, the nonprofit sector, federal and state agencies, formal and non-formal educators and education centers, tribal representatives, the fishing community, aquatic recreation communities, and interested members of the public. A list of Workshop organizers and facilitators can be found in Appendix A, along with Workshop participant affiliations.

Great care was taken to develop an Assessment that incorporates the priorities of both researchers and broader community members. Importantly, the Workshop agenda was crafted to foster a neutral space for dialogue among a diversity of individuals on a challenging issue. Organizers provided opportunities for written and verbal participation throughout the Workshop to ensure every individual would be able to have their perspectives documented.

...the Workshop agenda was crafted to foster a neutral space for dialogue among a diversity of individuals on a challenging issue.

Agenda and Structure

The Agenda and overall structure of the Workshop can be viewed in Appendix C. The Workshop was prefaced by a briefing document and draft list of research needs, supplemented by a series of brief informational talks at the beginning of the Workshop.

Sea Grant's goal was to ensure that all Workshop participants held a similar baseline familiarity with the DDT+ issue within Southern California. The Workshop began both days by providing short informational talks about the cultural and ecological context of the Southern California Bight and the current knowledge of the deep ocean DDT+ disposal site extent and impacts. Recordings of the Keynote Speakers on each day of the Workshop are available on the workshop website, and a list of speakers can be found in Appendix D.

Most of the two-day Workshop was spent in small groups, each focused on one of three themes:

1) Site Characterization

2) Environmental and Ecological Health

3) Human Health and Well-Being

Breakout rooms were kept to approximately 8-12 attendees to facilitate robust discussion. There were two breakout rooms focused on site characterization, three breakout rooms focused on environmental and ecological health, and two breakout rooms focused on human health and well-being. Each breakout room had a facilitator, a notetaker, and at least one subject matter expert to help answer more technical questions as they arose. Sea Grant asked Workshop participants to discuss 1) individual research needs and 2) higher-level research categories that described a group of related research needs.

Within breakout groups, Workshop participants engaged in facilitated discussions to identify any required modifications to the draft research needs and indicate which research questions are of high priority to their organization. Then Workshop participants evaluated the level of **impact** (informs decision-making or influences other areas of research) and **effort** (funding, time, or personnel required to complete research within a category) to address overarching research categories (Appendix E). In particular, working through the impact and effort exercise was challenging for Workshop participants; some found it difficult to assign a single relative amount of impact or effort to grouped research needs, as individual research needs sometimes have nuances in the effort needed or the potential impact. However, the challenging nature of this facilitated activity drove participants to talk through the logic of what areas of research are most enabling of other research areas, as well as to identify barriers to addressing these research needs.

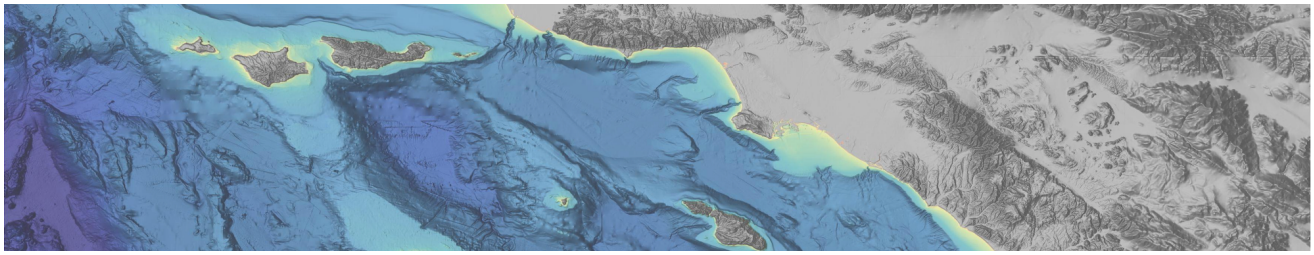
Following the Workshop, Sea Grant drafted a new iteration of the research needs that incorporated feedback from Workshop participants on which research categories are critical, as well as the impact of research categories compared to the effort required to accomplish the research. The narrative of research needs that resulted from Workshop discussions led Sea Grant to organize the research categories in an adaptive model that illustrates how areas of research best support one another and could be prioritized for more effective funding investments. The results and synthesis of these breakout room discussions are summarized in the *Findings* section of this report.

Community Listening Sessions

Sea Grant was invested in ensuring an iterative and inclusive DDT+ Research Needs Assessment, and thus planned for additional engagement of communities and organizations who were unable to attend the Workshop. We hosted a series of voluntary, virtual listening sessions with DDT+ technical experts, interested community members, and tribal representatives who were either unable to attend the July Workshop or were interested in providing further input on a draft of the Assessment report. The listening sessions were advertised to Workshop attendees and the USC and California Sea Grant listservs.

Five one-hour listening sessions were hosted in November 2022, with approximately 5-20 participants per session. Each session included a recap of the themes identified from the Workshop (outlined in this report) and guided discussion of participants' perspectives on the critical research needs relating to the deep ocean disposal of DDT in the Southern California Bight. The additional findings from these efforts were incorporated in the final version of this Assessment Report.

FINDINGS



Below we describe a number of findings from our Assessment: 1) an extensive list of research needs organized by theme and research categories; 2) classification of research categories in terms of impact and effort; 3) identification of high priority research needs; 4) a proposed adaptive model of how research areas relate and build on one another; and 5) a synthesis of those immediate actions necessary to effectively mobilize deep ocean DDT+ research in the Southern California Bight.

Research needs are organized within three themes (with the respective color classification of **Site Characterization**, **Environmental and Ecological Health** and **Human Health and Well-Being** following the organization order depicted in Figure 2. Workshop participants were provided opportunities to denote high-priority research needs for their organization. As depicted in Figure 2, any research needs that were noted as a priority by multiple Workshop participants across breakout discussions are **starred (*) and bolded** in the research need lists below, and those that received the most attention as a high priority research need are **starred twice (**) and bolded** in the sections below.

***Figure 2**: A representation of how research needs are organized into overarching categories and themes.*

Sea Grant acknowledges that many research needs cut across these three themes, as was reflected in Workshop discussions, but found the themes useful to focus Workshop discussions and analyses. The list of research needs within each Workshop theme is organized into overarching categories of related research needs. Each research need could become a distinct individual research project or a series of research projects.

We present an adaptive model that illustrates how research categories relate and could iteratively build on one another to efficiently increase overall understanding and impact. The model consists of a tiered structure; research categories that are in lower tiers provide the basis for research scope (e.g., research sites, chemical congeners examined, species tested, etc.) for research categories in higher tiers. The "Scoping" tier is the most basal and includes research categories that characterize the scope of deep ocean DDT+ contamination in the SCB. The next tier, "Pathways and Impacts," includes two levels of research categories that determine how DDT+ enters and impacts the marine ecosystem and coastal human communities.

While research categories in different tiers may be pursued concurrently, research scope and approach should adapt as more information is learned at lower tiers of the models...

The final "Mechanisms" tier includes research categories that elaborate on research in lower tiers to provide the fullest understanding of mechanisms of DDT+ impacts and next steps. While research categories in different tiers may be pursued concurrently, research scope and approach should adapt as more information is learned at lower tiers of the models presented throughout this section of the report.

Workshop participants evaluated the level of **impact** (informs decision-making, influence or enable other areas of research) and **effort** (funding, time, or personnel required to complete research within a category) to address overarching research categories (Appendix E). The general consensus for **impact vs. effort** is noted below for each research category.

Site Characterization

We define **Site Characterization** as research that examines the extent and movement of DDT+ waste related to deep ocean disposal sites of the Southern California Bight, including within sediments, the water column, and in the deep ocean food web. This also includes an assessment of exactly what DDT+ chemicals and mixtures are present and the feasibility of remediation.

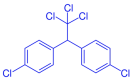
Recent findings have highlighted the following topics regarding the characterization of deep ocean DDT+ sites in Southern California:

Geographic scope of disposal sites: The two deep-water ocean disposal sites of focus in this Assessment (Disposal Sites #1 and #2, see Figure 1), are approximately 10 miles from the Palos Verdes Shelf. Disposal Site #1 encompasses multiple slopes in the Santa Monica Basin and thus contains a mix of depths. In contrast, Disposal Site #2 is located at the deepest extent of the San Pedro Bight (~900 meters) and is relatively flat. These topographic characteristics may drive differences in the transport and fate of DDT+ by biological and non-biological mechanisms, as well as pose unique challenges to study each site. Scientific surveys suggest that even beyond these two deep ocean sites, "short-dumping" in transit to the disposal sites was commonplace, and therefore the geographic scope of DDT+ disposal may be beyond these two sites [12]. There are 14 total known deep-water disposal sites that were used between the 1930s-1970s for refinery wastes, filter cakes and oil drilling wastes, chemical wastes, refuse and garbage, military explosives, and radioactive wastes [5].

Volume of DDT disposed: Extrapolating from numbers reported by Montrose, approximately 40,000 lbs per year of DDT+ mixed in acid waste could have been disposed of at sea between the 1940s and 1960s [1], roughly equivalent to the total volume disposed of on the Palos Verdes Shelf. Recent studies also confirmed that some sediments in the San Pedro Basin had DDT concentrations exceeding those found at the Palos Verdes Superfund site [4].

Method of DDT disposal: Although remotely operated vehicle (ROV) surveys identified numerous drums disposed on the San Pedro Basin seafloor and DDT+ contaminated sediment nearby these drums, the highest sediment concentrations of DDT+ were not found near drums [4]. EPA's archival research indicates that DDT+ waste was largely bulk-dumped directly into the ocean rather than contained in drums [5]. It is still unknown to what extent there was actually DDT+ waste in the drums.

Future of Deep Ocean DDT+ Contamination: DDT+ sediment concentrations in these deep basins are most likely controlled by sediment exchange, drum leakage (depending on the extent that drums contain DDT+), ocean currents, biological interactions, and chemical interactions of DDT+ with the water column, sediment, pore water, and suspended particulates. The physical characteristics of the deep-water basins allow water stratification, hypoxia, and anoxia to occur, which may further slow the biodegradation of DDT+ residues. However, there is still sufficient water movement to move material into, within, and out of the deep basins (on a timescale of months) and fully circulate the water within the basins (on a timescale of a few years) [13], meaning it is possible for DDT+ to escape the basins into surrounding habitats.



Diversity of DDT-related compounds and related byproducts: Scientists now understand that there is a much broader suite of DDT breakdown products and related byproducts (collectively referred to as "DDT+") that can have toxic effects but are not traditionally monitored in the environment (and thus may be underestimated). Recent studies have detected DDT+ compounds in marine mammals living in the Southern California Bight [1] as well as a diversity of DDT+ compounds commingled with petroleum products in the deep ocean sediments of the San Pedro Basin [4].

A Research Agenda for Site Characterization of the Deep Ocean DDT+ Disposal Sites:

It is critical to build on existing research conducted within the San Pedro and Santa Monica Basins to expand our understanding of what DDT+ compounds have persisted and are entering the food web. Below we present an adaptive model (Figure 3) of how the following **Site Characterization** research categories relate and build on one another based on our Assessment and provide further explanation of the placement of each of these research categories.

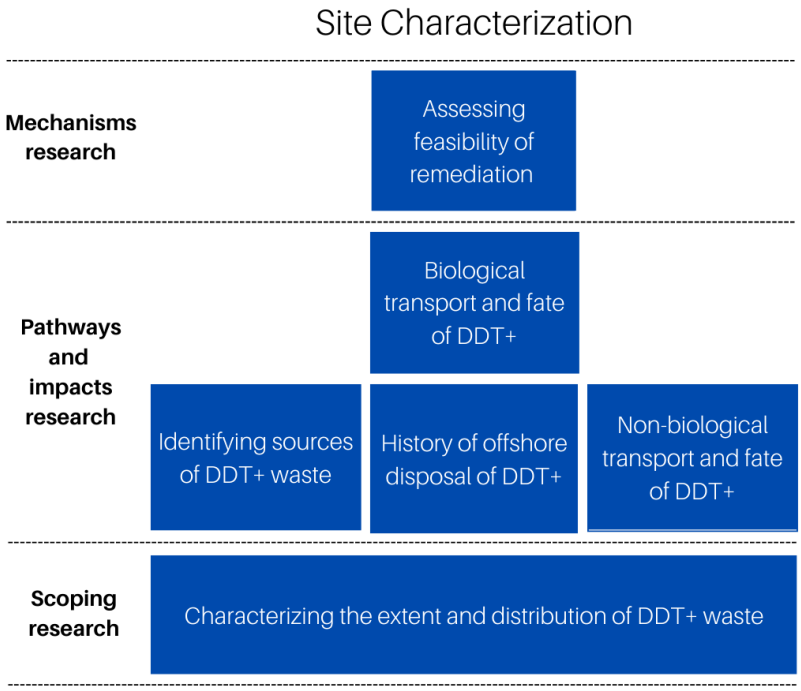


***Figure 3**. Adaptive model of research categories within the Site Characterization theme*

Characterizing the Extent and Distribution of DDT+ Waste

The Assessment identified this research category as having one of the **highest impacts** on other categories of research. It is important to document: 1) the full spatial extent of DDT+ waste (i.e., sediments, water column, relevant biological samples); 2) what type of DDT+ chemicals and other wastes are present; and 3) what organisms within the deep ocean food webs contain DDT+. This will provide foundational context to enable researchers to assess impacts of the deep ocean DDT+ on local ecosystems and human communities.

Generally classified as an overarching research need, many participants agreed that these sub-questions (provided below) could enable the work of other important research needs in all three themes. For example, characterizing the full physical, chemical, and biological extent and distribution of DDT+ waste would identify what oceanographic conditions and aspects of deep ocean food webs should be focal points in characterizing the physical and biological transport and fate of DDT+. While there is significant focus on mapping Disposal Sites #1 and #2 (see Figure 1), participants noted the importance of exploring beyond these sites as past research found evidence of disposal extending from nearshore out into the basins [4].

There is **variable effort** required for these research projects, as there are diverse levels of technological, financial, and accessibility challenges to conduct widespread ship surveys of sediments and marine life at depths of 900 meters. Importantly, there are: (1) an unknown

number of relevant archived sediment and biological samples from pertinent sites; and (2) existing research efforts that can be leveraged to gain initial insights into some of the research needs. There is value to be gained from gathering additional samples in a planned and coordinated way; future research efforts could yield greater benefits if collaborations are formed to collect multiple types of samples and data to address multiple research needs and prevent siloing (e.g., adding some sampling to existing California Cooperative Oceanic Fisheries Investigations surveys).

- **What is the spatial extent and distribution of DDT+ contamination in sediments throughout the San Pedro and Santa Monica Basins, including potential DDT+ hotspots?****
- **What organisms comprise the food web in the deep ocean basins and interact directly or indirectly with DDT+ waste?***
- **What DDT+ chemicals are present in the organisms living in and migrating through the deep ocean basins and at what concentrations?***
- What are DDT+ concentrations in the water column in contact with contaminated sediments?
- What is the vertical distribution of DDT+ concentrations within sediments and pore water
- What is the most efficient way to survey sediment contamination in the basins, and how much site location accuracy is required?
- How does the additional information provided by non-targeted monitoring of DDT+ chemicals, including impurities, alter our understanding of the extent and distribution of DDT+ chemicals in the Southern California Bight?
- Are there other major chemical contaminants of concern that were disposed in the same area as DDT+ waste?
- How bioavailable is DDT+ waste to organisms living in, on, or near the sediments?

Non-Biological Transport and Fate of DDT+ Waste

This category refers to the physical and chemical processes by which DDT+ waste is transported and degraded, contributing ultimately to where and how long deep ocean DDT+ remains in the environment. This research need category was identified as having a **moderate impact** on natural resource management. Further, although there are existing methods that enable basic modeling to be done with minor effort, it requires **more effort** to develop comprehensive, management-relevant transport or fate models and ground truth them using ship surveys. By identifying the future movement and fate of DDT+ waste, these research needs will identify future site monitoring and remediation needs.

- How does the mode of offshore disposal (containerized vs. bulk dump) affect the disposition of DDT+ waste today?
- What are the mechanisms of DDT+ transport by ocean currents?
- What is the rate of transport of DDT+ from the disposal sites to sites of particular importance to human communities and ecosystems?
- What are the interactive chemical effects between DDT+, seawater, suspended organic particles, and other chemical contaminants present in the deep ocean basin (e.g., petroleum tar cakes)?
- What is the structural integrity of the drums and how much waste is escaping now and as the drums degrade?
- Is there a connection or transport of DDT+ between the Palos Verdes Shelf and deep ocean disposal sites?
- What is the relative role of physical transport processes in driving transformation of DDT+?
- How do climate change and extreme weather events change the level of disturbance and transport of DDT+ within the ecosystem?
- How do TCPM and TCPM-OH derive from or relate to DDT (i.e., are they technical byproducts of DDT production)?
- How might future activities that impact the seafloor (e.g., mining, cable laying, aquaculture derived sedimentation, etc) influence DDT+ fate in the SCB?

Identifying Sources of DDT+ Waste

This research need category was identified overall as having a **high impact** on natural resource management. By using non-targeted analyses, unique chemical fingerprints may be identified for different types of DDT+ waste (e.g., containerized, non-containerized) and potentially be connected to the source of the material. Identifying sources and patterns in the chemical composition of DDT+ waste enables more targeted assessments of biological transport of DDT+ in the Southern California Bight, in addition to other ecological and human health impacts. Addressing these research questions will require **moderate effort** as new sample collection and chemical analysis of samples are required.

- **Can sources of DDT+ contamination be identified using unique chemical fingerprints of DDT+ and other waste (e.g., DDT:PCB ratios, etc.)?***
- **What DDT+ and other wastes reside inside of the disposed barrels, and can types of waste be characterized by barrel family?***

- **Do the chemical signatures (i.e., "fingerprints") of deep ocean DDT in sediments carry through the food web?***
- How does the chemical composition of DDT+ waste from ocean disposal relate to DDT+ waste from stormwater and sewer discharges in the Dominguez Channel and discharges to the Palos Verdes Shelf?

History of Offshore Disposal of DDT+

Another needed research area is to investigate archival written or oral documentation of what DDT+ wastes were disposed of at or en route to deep ocean disposal sites. This research need category was identified as having a **moderate impact** on natural resource management, but it was considered a "quick-win," as it requires only a **low-medium effort** to examine the archived documentation, inform future research needs, and identify responsible/liable parties. Put together with *Identifying Sources of DDT+ Waste* research needs, this information will provide a more comprehensive understanding of what DDT+ and other waste was documented to have been disposed and what waste still remains to impact current and future coastal ecosystems.

- What companies were dumping or contracting disposal of DDT+?
- What was the mixture of DDT+ waste that Montrose supplied to salvage companies to dump?
- What amount of DDT+ was disposed of and over what time period?
- What amount was containerized as opposed to bulk dumped?
- Where and at what depths was containerized and bulk dumping documented?

Biological Transport and Fate of DDT+ Waste

This category refers to the biological processes by which DDT+ waste is transported and degraded, contributing to where and how long deep ocean DDT+ ultimately remains in the environment. Before these research needs can be addressed, living organisms in deep ocean basins must be characterized (see *Characterizing the Extent and Distribution of DDT+ Waste*). This research need category was identified as having a **moderate to high impact** on natural resource management. It requires **moderate to high effort** to observe interactions of deep water organisms with DDT+ contaminated sediments and measure movement of DDT+ waste resulting from biological activity.

Collaboration between labs and a sample database could increase the sharing of existing archived samples to lower the effort needed for some of these research questions (see *Immediate Actions to Advance DDT+ Research* in the *Synthesis* section of this report).

Similarly to the *Non-biological Transport and Fate of DDT+ Waste* category, this research will identify how site monitoring and impacts may need to change over time, including how far DDT+ compounds could be transported by highly migratory coastal organisms (e.g., marine mammals, condors).

- **What role(s) do microbes and benthic biota play in transforming DDT+ and other chlorinated compounds, and are microbial transformations beneficial?***
- **At what rates are microbial communities degrading DDT+ and how do taxa differ in degradation rates or pathways?***
- **Given current microbial degradation rates, what is the long term fate of DDT and derivatives in sediments and the water column, and is this fate impacted by oxygen concentrations, co-contaminants, and depths?***
- What are the mechanisms of DDT+ dispersal by biological communities?
- Does animal activity affect the vertical distribution and/or remobilization of DDT+ in sediments?

Assessing Feasibility of Remediation

This category deals with research that assesses the feasibility and impact of remediating deep ocean DDT+ disposal sites. This category of research needs was considered to have a **moderate to high impact** on natural resource management and to require **high effort** due to the amount of data that would first need to be gathered to assess effective and safe options for remediation of deep ocean DDT+ disposal sites. Globally, there are no existing precedents for remediation of any ocean sites as deep as 900m, leaving many questions about the feasibility and regulatory processes that would be required to accomplish this. Workshop participants had varying opinions regarding the importance of prioritizing remediation as the ultimate goal of research investment.

Participants highlighted the importance of additional conversations and exploration regarding the feasibility, potential impacts, and prioritization of remediation over other DDT+ research needs.

- Can environmentally friendly methods be applied to enhance microbial degradation? Will this pose an additional risk if microbial metabolism still produces dangerous byproducts?
- Based on the extent and fate of DDT+ waste in the region, what options are feasible for remediation or otherwise reducing contamination of the deep ocean sites?
- What are the potential impacts of remediation activities?
- How feasible is it to mitigate 100% of the contaminated sites compared to focusing on hotspots of greatest concern?

Environmental and Ecological Impacts

We define **Environmental and Ecological Impacts** as research that examines the scope of direct and indirect impacts of deep ocean disposal of DDT+ in the SCB on the organisms who have lived in or moved through these areas over the past 80 years.

Previous studies have shown that lower trophic level organisms—like plankton and some fish—can uptake DDT+ by: (1) direct absorption through the water; (2) consuming particulates; and (3) by bioaccumulation through their diet [14–16]. Higher trophic level organisms—like marine mammals and humans—are exposed to DDT+ primarily through diet, accumulating DDT+ in their fat stores. At each increase in trophic level within the food web, biomagnification leads to increased DDT+ levels, causing higher trophic levels to be at a higher potential risk for DDT+ toxicity [17].

There are still many unknowns about the attributable impacts of the deep ocean disposal of DDT+ on Southern California ecosystems. Below are some examples of the current understanding of DDT+ impacts on Southern California wildlife:

Birds: Many California coastal birds, such as bald eagles, peregrine falcons, California condors, and California brown pelicans, have shown signs of reproductive decline, such as eggshell thinning, correlated with DDT+ exposure and reduced hatching success [18–20].

Marine Mammals: California pinnipeds (seals, sea lions) and cetaceans (e.g., bottlenose dolphins) in the Southern California Bight have higher concentrations of DDT+ than similar species anywhere else in the world [21–26]. Higher levels of DDT+ in female sea lions within the Southern California Bight have been correlated with premature births [26, 27]. Further, DDT+, PCBs, and other mixed contaminant exposures may contribute to immunosuppression and cancer in California sea lions and marine mammals [23, 26, 29–35]. The EPA states that DDT and PCBs play a significant role as primary carcinogens and as co-factors; for example, there is strong evidence showing the link between organic pollutants and urogenital carcinoma, a specific type of cancer that originates in the reproductive tract and rapidly metastasizes throughout the body of California sea lions [33]. However, marine mammal DDT+ concentrations appear to be decreasing over time, as would be expected if regional sediment DDT+ concentrations are decreasing over time with burial and degradation [20].

Fish: A number of fish species sampled from the Southern California Bight (including white croaker, longspine thornyhead rockfish, shortspine thornyhead rockfish, lanternfish, and deep-sea rattail fish) had high concentrations of DDT+ in their tissues [1, 36]. White croaker sampled in the 1980s from San Pedro Bay had a

reduced ability to reproduce, correlating with elevated levels of DDT+ in ovarian tissue [37]. The California Office of Environmental Health Hazard Assessment (OEHHA) maintains some fish consumption advisories based on DDT near the Palos Verdes Shelf [38].

Invertebrates (e.g. crab, lobster, polychaete worm, nematode): Elevated concentrations of DDT+ in macroinvertebrates from disposal sites 1 and 2 were documented in Chartrand et al., 2022 [1]. Invertebrates, if contaminated, could be a potential pathway to transfer DDT+ to higher trophic levels such as bottom-dwelling fish [1].

A Research Agenda for Environmental and Ecological Health Impacts of Deep Ocean DDT+:

Most existing research within this theme has focused on DDT+ impacts on nearshore food webs, providing a starting point to understand how DDT+ may transfer through and impact deep ocean food webs. Below we present an adaptive model (Figure 4) of how the following **Environmental and Ecological Health** research needs relate and build on one another based on our Assessment and provide further explanation of the placement of each of these research categories.

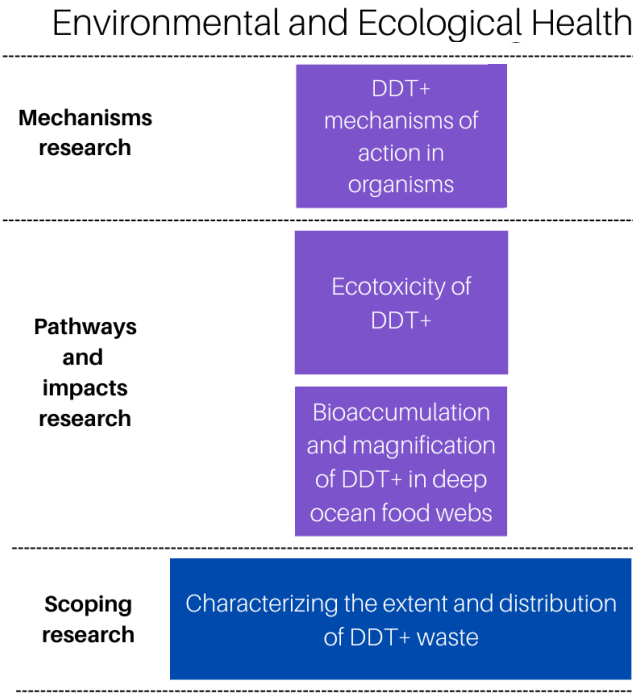


***Figure 4**. Adaptive model of research categories within the Environmental and Ecological Health Theme*

Characterizing the Extent and Distribution of DDT+ Waste

Most participants agreed that the first step towards understanding **Environmental and Ecological Health** impacts would be measuring and characterizing DDT+ in deepwater biota. Throughout the Assessment, we heard a strong desire to study the deep ocean food web in more detail. This is clearly a necessary and impactful missing piece of information for all interested parties to understand how and to what extent DDT+ moves from deep ocean sediments or barrels into marine and coastal food webs. Therefore, this category is also included under this theme. Please see the full description of research needs for this category in the previous **Site Characterization** section.

Bioaccumulation and Magnification of DDT+ in Deep Ocean Food Webs

This research needs category was identified as **medium to high impact** and **low to medium effort.** Researchers already know mechanistically how some DDT compounds bioaccumulate in fat tissue and biomagnify through food webs into higher-level predators, particularly in shallow ocean waters. Once there is better documentation of which deep sea species are interacting with DDT+ waste and one another, researchers then can begin piecing together how DDT+ may be bioaccumulating through deep ocean food webs. Further, how DDT+ is bioaccumulated (and potentially biomagnified) through the food web is foundational to determine which organisms (and which groups of people) will be at highest risk for negative health impacts.

- **How do different local marine species accumulate DDT+ over their lifetime (i.e., bioaccumulate)?***
- **By what pathways does deep ocean DDT+ get passed up the food web (i.e., bioaccumulated, biomagnified)?***
- What factors (e.g., age, sex, metabolism, behavior, life history) influence local organisms' DDT+ concentrations?
- How are DDT+ concentrations in marine organisms and coastal wildlife changing over time (i.e., can we leverage existing time series)?
- What are the implications of marine life migration on the spread of DDT+ in non-local food webs?

Ecotoxicity of DDT+

Ecotoxicity research focuses on the effects of natural or man-made substances on living organisms. Workshop participants considered assessing the ecotoxicity of DDT+ in marine and coastal organisms a **high impact** but also a **high effort** research need. Once we understand

the bioavailability of DDT+ chemicals and how they accumulate and magnify throughout local food webs, ecotoxicity studies are the next critical step to understand the extent to which environmentally-relevant concentrations of DDT+ are toxic to coastal organisms. Data obtained from these research categories should be used to develop new ecological risk models, as previous models did not incorporate the broader range of species and DDT+ compounds that can be examined.

This research will require more effort as researchers also consider how other factors and co-stressors (e.g., temperature, ocean acidification and hypoxia) may mitigate or amplify toxicity; it can be difficult to pull apart various stressors and deduce their effects. Notably, some participants mentioned that research incorporating co-stressors could lead to more avenues for funding.

- **Are there acute (e.g., harmful algal blooms) or chronic (e.g., food web changes) co-stressors that exacerbate DDT+ toxicity for marine organisms and coastal wildlife?****
- **What are the exposure thresholds for shorter- and longer-term negative impacts of DDT+ on marine organisms and coastal wildlife living in the SCB?***
- **What are the impacts of the mixture of DDT+ compounds on the health, community structure, and functional diversity of SCB marine mammals and other wildlife?***
- **What are new minimally invasive methods or biomarkers to determine life history characteristics to better understand contaminant effects over time and reduce reliance on sampling stranded marine mammals?***
- **What new technologies and/or approaches can determine the contribution of DDT+ toxicity (as opposed to other causes) in causing lower reproductive success, cancers, immunosuppression, endocrine disruption, etc in marine organisms and coastal wildlife?***
- **How does the simultaneous exposure to DDT+ and other contaminants affect the health of marine organisms and other wildlife?***
- What factors (e.g., age, sex, metabolism, behavior) influence DDT+ toxicity in marine organisms and coastal wildlife?

Mechanisms of Action of DDT+ Impacts

Mechanisms of action of DDT+ refers to the internal processes of *how* these chemicals have effects on various organisms (e.g. what is happening at a cellular or molecular level). Most Workshop participants agreed that the questions of *if* there are negative effects, and if so, *where* they may be concentrated (i.e. hotspots or in the food web) should be answered before

delving deep into the mechanisms of action. However, the mechanisms of action provide the benefit of informing which species are more likely to be negatively impacted by DDT+ and at what exposure levels.

Some of this research—especially if it is well grounded in information coming in from the "Scoping" research categories—may be able to occur in tandem. However, most participants agreed that research needs in lower tiers should be prioritized first. Workshop participants classified this research category as a **low-mid impact** and **higher effort** item.

- What mechanisms of action for DDT+ impact marine organisms and coastal wildlife?
- How do interactive effects of other contaminants affect DDT+ mechanisms of action on marine organisms and coastal wildlife?
- What are the mechanisms by which DDT+ causes reproductive defects in the California condor?
- What are the mechanisms by which DDT+ causes cancer, immunosuppression, and endocrine disruption for marine mammals living in the SCB?

Human Health and Well-Being

We define the **Human Health and Well-Being** theme as research examining whether humans living or recreating in the Southern California Bight are at risk of physical, mental, and/or social impacts from deep ocean disposal of DDT+ and how that risk could best be mitigated.

DDT is classified by the U.S. EPA as a "probable" human carcinogen—this means that scientific studies have shown that there is a causal relationship between DDT exposure and cancer, but the data is primarily from animal studies with limited human data to date. DDT is also classified as an endocrine disruptor in humans, which can lead to possible developmental effects due to hormone disruption. DDT exposure is thought to contribute to obesity in humans [39], in addition to having trans-generational effects where DDT exposure during pregnancy can correlate with higher rates of breast cancer, hypertension, and obesity in daughters [40], and early onset of puberty and adult obesity in granddaughters [41].

However, there has yet to be research specifically focused on whether the deep ocean disposal sites pose a risk to human health and well-being. The U.S. EPA recently stated that "based on recent monitoring, if appropriate Fish Advisories are followed, eating fish caught in the Southern California Bight is safe" and that given the depth and location of the deep ocean disposal sites, "it is unlikely that recreational diving, snorkeling, or other water contact activities are conducted near this disposal site" [5].

A Research Agenda for Human Health and Well-Being Impacts of Deep Ocean Disposal of DDT+:

It is critical to consider how to leverage existing or easily obtained information to make informed decisions to protect people *now*, while the necessary extensive characterization of the impacts of this broad suite of DDT+ chemicals are being explored. Human research can be expensive, time-consuming, and difficult, thereby requiring a hard look at what research is absolutely necessary to mitigate risk. Below we present an adaptive model (Figure 5) of how the following **Human Health and Well-Being** research needs relate and build on one another based on our Assessment and provide further explanation of the placement of each of these research categories.

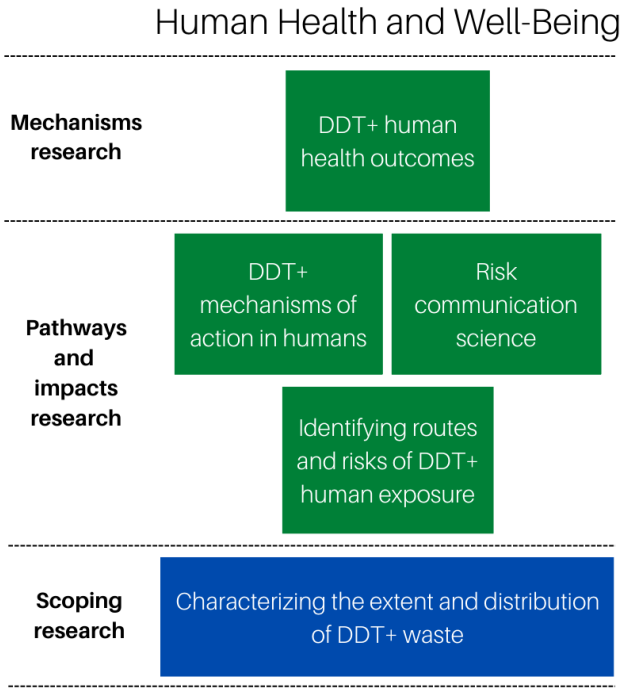


Figure 5. *Adaptive model of research categories within the Human Health and Well-Being Theme*

Characterizing the Extent and Distribution of DDT+ Waste

Understanding human health impacts of deep ocean DDT+ will be grounded in understanding gained from the characterization of the deep ocean disposal sites: DDT+ concentrations, extent, and bioavailability within the environment and to the food web of which we are a part. Therefore, we included this category here as well. Please see the full description of research needs within this category in the **Site Characterization** section.

Identifying Routes, Risks, and Mitigation of DDT+ Human Exposure

This category includes research assessing how humans are exposed to DDT+ originating from ocean disposal sites, associated risk, development of risk models based on the best available science, and possible mitigation of those exposures. It is most critical to first establish routes and levels of human exposure to DDT+ in order to mitigate further exposure and direct future research for human health and well-being. This category of research was generally considered **high impact** with **medium/variable effort.**

Understanding bioavailability, especially in high-use areas like fishing locations, harvesting areas and other recreational spots, in addition to concentration levels, will help establish and understand "hotspots" of exposure risk. Seafood safety was discussed extensively in terms of analyzing the most probable route of past, current, and future exposure. It is important to ensure that the seafood being sampled are actually those types that are actively being caught or harvested.

Special consideration should be given to the differential vulnerability of human populations due to underlying health conditions or increased exposure due to subsistence harvesting, cultural diets, or the availability of particular kinds of seafood. Monitoring frequently consumed fish species and even using marine mammals as sentinels are strategic approaches to understanding the contaminant landscape. Additionally, the additive or synergistic effects of exposure to multiple chemicals (e.g. DDT+, mercury, PCBs) in seafood will be important in developing seafood advisories.

- **What are the strategies to mitigate risk to local communities who recreate and subsist in these waters?****
- **What are the routes of human exposure to and associated risk from deep ocean DDT+ including via current subsistence, recreational, and commercial activities?***
- **What populations (defined geographically, socioeconomically, and/or by existing health burdens) are likely to be most at risk of DDT+ exposure?***
- **What local marine organisms are commonly consumed by humans (via fishing or aquaculture) and how much DDT+ do they contain?***
- **What changes are needed to local seafood consumption recommendations based on new approaches to monitor DDT+ concentrations and new understandings of DDT+ human health impacts beyond cancer risk?***
- **Are there existing signals of exposure to DDT+ (i.e., biomarkers) among those most likely to have been affected (local residents and/or frequent users of the Southern California Bight)?***
- How does human exposure to DDT+ via consumption compare to that of upper trophic level marine and coastal organisms?
- What is the bioavailability of DDT+ to humans via different exposure pathways?
- At what contaminant thresholds does DDT+ toxicity occur and does it differ among communities with different consumption patterns or vulnerability?
- Are there human exposure biomarkers that could distinguish the source of DDT+ exposure between the Palos Verdes Shelf, deep ocean disposal sites, Dominguez Channel, or other sources?

- What are the risks associated with future uses of the disposal site areas, and how can exposure be mitigated?
- What monitoring approaches could be applied by agencies as part of expanded standardized testing for DDT+ to inform offshore development siting (e.g., aquaculture) in the Southern California Bight?

Risk Communication Science

This category includes research that will improve our understanding of how to best communicate the relative risks of exposure to ocean DDT+ to a diversity of communities. This research need category was labeled as **low/medium effort** with **high impact** because effective risk communication will be critical to give communities the information they need to make decisions about their health. The research needs in this category should sequentially come after we understand the actual risk and how that risk varies by geography, exposure activity, and compounded health risks. Partnerships with trusted communicators and community partners will be critical to work accurately, effectively, and in a culturally sensitive way.

- **What are best practices to communicate the relative risk of deep ocean DDT+ to local communities? Recreational, subsistence, or commercial users (e.g., commercial fishermen, anglers, aquaculturists)?****
- Have there been impacts on recreational use (i.e., change in public enjoyment or use now that people know about offshore disposal) and commercial activity (i.e., change in public interest in purchasing local seafood or support for aquaculture areas) due to public perceptions of DDT+ impacts?

DDT+ Human Health Outcomes

Workshop participants felt that "proof of need" (i.e., detectable human exposure) was first required to justify expensive and long-term research in DDT health outcomes. This category of research needs was considered to have **medium impact** and require **variable effort** with research ranging from using archived biological samples/literature reviews (lower effort) to longitudinal epidemiology studies (higher effort). Participants noted that although many DDT epidemiological studies exist, the impacts and possible synergistic effects of the 45+ DDT-related compounds and co-stressors should be considered in future research in this area. Further, participants suggested that marine mammals be used as the sentinels of human contaminant exposure and could give a glimpse of heavy exposure and impact to mammalian systems.

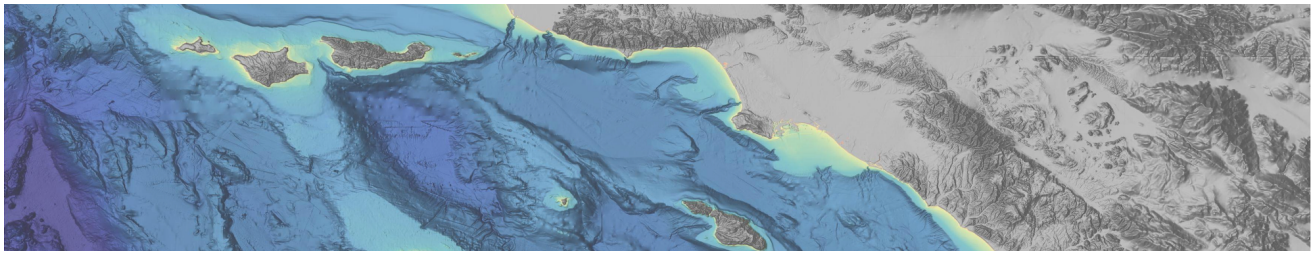
- **What can we learn from longitudinal epidemiological studies (i.e., tracking health outcomes of people with DDT+ exposure over time) about the major human health effects of those DDT+ compounds & concentrations detected in this region?***
- Are there other regions that have similar challenges of DDT+ exposure that would provide more context for potential human health effects or impacts?
- What can we learn from laboratory studies (i.e., animal studies, in vitro studies) about the metabolism and probable human health effects of those DDT+ compounds detected in the Southern California Bight region?
- How do compounded health risks affect vulnerability to DDT+ risk?

Mechanism of Action of DDT+ Impacts

Mechanisms of action of DDT+ refers to the internal biochemical processes by which these chemicals have negative effects on people (e.g. what is happening at a cellular or molecular level). This research needs category was placed higher in the adaptive model because of the great expense, **high effort** required, and **lower impact** in the short-term in determining necessary risk mitigation and communication efforts. Ultimately, though, it is important to understand how DDT+ impacts the body, particularly through potential additive or synergistic effects of the various DDT+ compounds with additional toxins like mercury or PCBs that exist in the Southern California Bight ecosystems.

- What are the mechanisms of action for observed associations between DDT and obesity & metabolic diseases, reproductive & neurodevelopmental impacts, and cancers?
- Do these mechanisms of action differ across the subset of DDT+ compounds detected/relevant in this region?
- Are there synergistic effects among the DDT+ suite of compounds that lead to higher risk for humans? Do these need to be accounted for in risk models?
- Are there particular methodological constraints/challenges that need to be optimized for these laboratory studies (i.e., what is the best matrix - sera/plasma etc.)?

Synthesis: A Deep Ocean DDT+ Research Agenda for the SCB

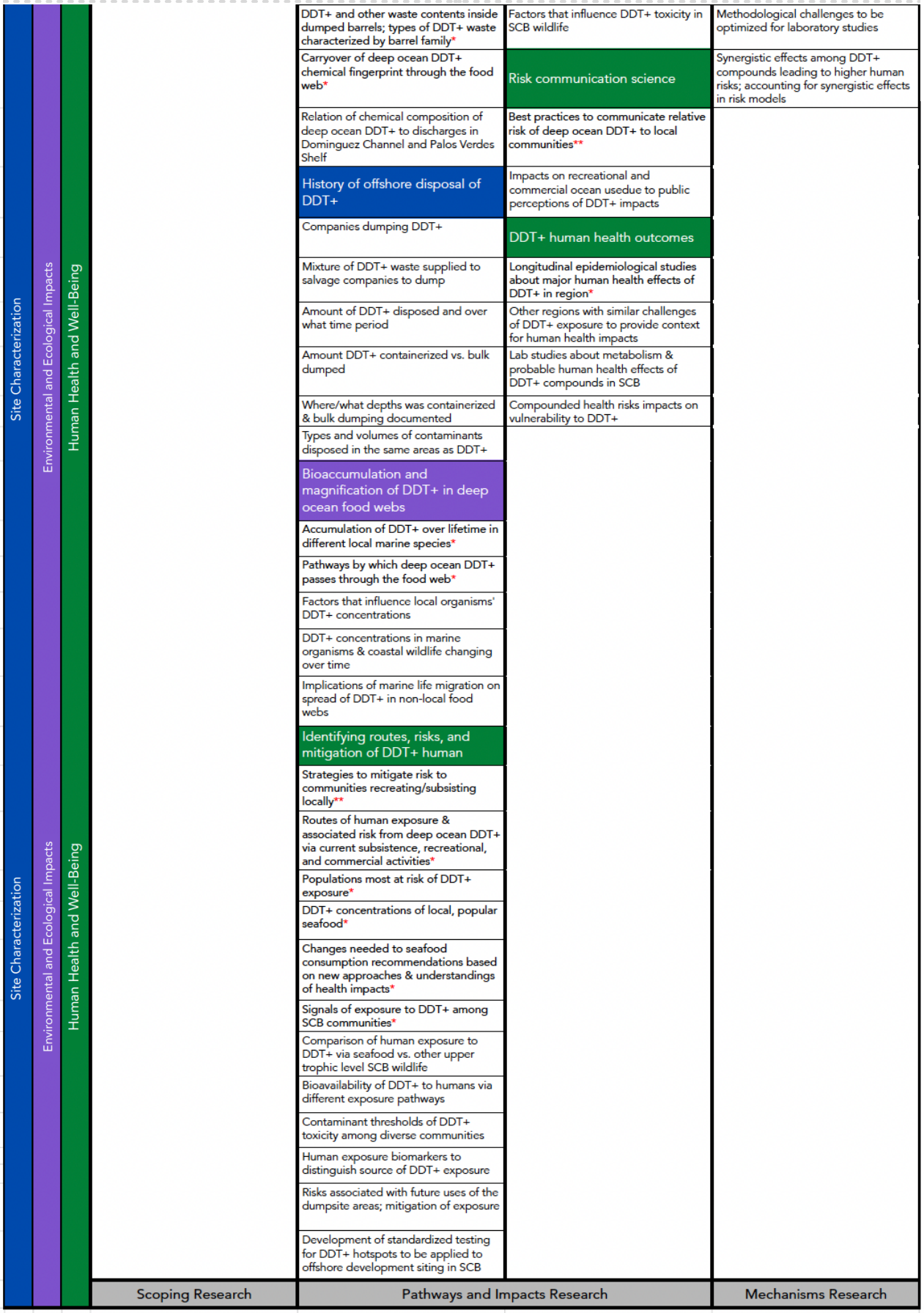


Altogether, the full list of research needs generated through Assessment discussions and presented in previous sections provides a comprehensive research agenda for deep ocean DDT+ contamination in the Southern California Bight. Please see Table 1 below for a snapshot of all of the research needs discussed in the previous *Findings* sections. ***Researchers should refer to the Findings sections above for the full description of research needs.***

Table 1: *A snapshot of California Deep Ocean DDT+ Research Needs, organized by research categories and thematic area. Note that this table abbreviates the description of each research need for ease of readability. Research needs identified as high priority are starred.*

Research Themes	Scoping Research	Pathways and Impacts Research		Mechanisms Research
Site Characterization; Environmental and Ecological Impacts; Human Health and Well-Being	Characterizing the extent and distribution of DDT+ waste	Non-biological transport and fate of DDT+ waste	Biological transport and fate of DDT+ waste	Assessing feasibility of remediation
	Spatial extent & distribution of DDT+ in sediments in basins, including hotspots**	Does containerized vs. bulk dumping affect disposition of DDT+ waste	Role(s) of microbes & benthic biota in transforming DDT+*	Environmentally friendly methods to enhance microbial degradation
	DDT+ chemicals & concentrations in organisms living in & migrating through the deep basins*	Mechanisms of DDT+ dispersal by currents	Differences in DDT+ degradation pathways and rates between microbial communities*	Feasible options for remediation based on extent and fate of regional DDT+
	Food web in the deep basins interacting w/ DDT+ waste*	Transport rate of DDT+ from dumpsites to important sites for humans & ecosystems	Long term fate of DDT+ in sediments & water given current microbial degradation rates; influence of oxygen, co-contaminants, depths*	Potential impacts of remediation
	DDT+ concentrations in water near contaminated sediments	Interactive chemical effects between DDT+, seawater, organic particles, & other contaminants	Mechanisms of DDT+ dispersal by biological communities	Feasibility to mitigate 100% of contaminated sites vs. hotspots
	Vertical distribution of DDT+ concentrations in sediments & pore water	Structural integrity of drums and changes in containment of waste over time	Animal activity impact on vertical distribution/remobilization of DDT+ in sediments	Mechanisms of action of DDT+ impacts on organisms
	Most efficient way to survey contamination in basins; whether site location accuracy is required	Connections between DDT+ from Palos Verdes Shelf and basin dumpsites	Ecotoxicity of DDT+	Mechanisms of action for DDT+ impacts on SCB wildlife
	Bioavailability of DDT+ waste to organisms associated with sediments	Role of physical transport processes in transforming DDT+	Acute or chronic co-stressors that exacerbate DDT+ toxicity for SCB wildlife**	Influence of interactive effects of other contaminants on DDT+ mechanisms of action
	How non-targeted monitoring of DDT+ redefines the extent and distribution of DDT+ in the Bight	Effects of climate change and extreme weather on disturbance and transport of DDT+	Thresholds for shorter- & longer-term negative impacts of DDT+ on SCB wildlife*	Mechanisms underlying DDT+ related reproductive defects in California condor
	Other major contaminants dumped in the same area	Relation of TCPM and TCPM-OH to DDT	Impacts of mixture of DDT+ compounds on health, community structure, & functional diversity of SCB wildlife*	Mechanisms underlying DDT+ related cancer, immunosuppression, & endocrine disruption in regional marine mammals
		Impacts of future seafloor activities on DDT+ fate	Minimally invasive methods/biomarkers to understand contaminant effects in non-stranded marine mammals*	Mechanisms of action of DDT+ impacts on humans
		Identifying sources of DDT+ Waste	Effects of simultaneous exposure to DDT+ & other contaminants on health of SCB wildlife*	Mechanisms of action for observed associations between DDT+ and negative health impacts
		Use of chemical fingerprints to identify sources of DDT+ contamination*	New approaches to determine contribution of DDT+ toxicity in causing negative health impacts in SCB wildlife*	Differences in mechanisms of action across DDT+ compounds in region

Note: Table is continued on the next page.


Site Characterization
Environmental and Ecological Impacts
Human Health and Well-Being
Site Characterization
Environmental and Ecological Impacts
Human Health and Well-Being
DDT+ and other waste contents inside dumped barrels; types of DDT+ waste characterized by barrel family*
Carryover of deep ocean DDT+ chemical fingerprint through the food web*
Relation of chemical composition of deep ocean DDT+ to discharges in Dominguez Channel and Palos Verdes Shelf
History of offshore disposal of DDT+
Companies dumping DDT+
Mixture of DDT+ waste supplied to salvage companies to dump
Amount of DDT+ disposed and over what time period
Amount DDT+ containerized vs. bulk dumped
Where/what depths was containerized & bulk dumping documented
Types and volumes of contaminants disposed in the same areas as DDT+
Bioaccumulation and magnification of DDT+ in deep ocean food webs
Accumulation of DDT+ over lifetime in different local marine species*
Pathways by which deep ocean DDT+ passes through the food web*
Factors that influence local organisms' DDT+ concentrations
DDT+ concentrations in marine organisms & coastal wildlife changing over time
Implications of marine life migration on spread of DDT+ in non-local food webs
Identifying routes, risks, and mitigation of DDT+ human
Strategies to mitigate risk to communities recreating/subsisting locally**
Routes of human exposure & associated risk from deep ocean DDT+ via current subsistence, recreational, and commercial activities*
Populations most at risk of DDT+ exposure*
DDT+ concentrations of local, popular seafood*
Changes needed to seafood consumption recommendations based on new approaches & understandings of health impacts*
Signals of exposure to DDT+ among SCB communities*
Comparison of human exposure to DDT+ via seafood vs. other upper trophic level SCB wildlife
Bioavailability of DDT+ to humans via different exposure pathways
Contaminant thresholds of DDT+ toxicity among diverse communities
Human exposure biomarkers to distinguish source of DDT+ exposure
Risks associated with future uses of the dumpsite areas; mitigation of exposure
Development of standardized testing for DDT+ hotspots to be applied to offshore development siting in SCB
Factors that influence DDT+ toxicity in SCB wildlife
Risk communication science
Best practices to communicate relative risk of deep ocean DDT+ to local communities**
Impacts on recreational and commercial ocean usedue to public perceptions of DDT+ impacts
DDT+ human health outcomes
Longitudinal epidemiological studies about major human health effects of DDT+ in region*
Other regions with similar challenges of DDT+ exposure to provide context for human health impacts
Lab studies about metabolism & probable human health effects of DDT+ compounds in SCB
Compounded health risks impacts on vulnerability to DDT+
Methodological challenges to be optimized for laboratory studies
Synergistic effects among DDT+ compounds leading to higher human risks; accounting for synergistic effects in risk models
Scoping Research
Pathways and Impacts Research
Mechanisms Research

Across all of the discussed research needs, four were most commonly noted as critical by Assessment participants *(not listed in order of importance)*.

- **Characterization of extent of DDT+ in deep ocean sediments.** Investing funding early in this critical research area will provide direction and management context to all other compiled human and ecosystem health research needs.

- **Examination of DDT+ toxicity in the context of multiple stressors in marine life.** There is still much to learn about the toxicity of the 45+ DDT-related compounds on local marine and coastal organisms. The combined effects of co-occurring environmental stressors in the natural environment — like warming temperatures, ocean acidification, harmful algal blooms, and contaminant exposure — will have considerably different impacts than if one artificially considers an organism experiencing each stressor in isolation. Such examination of co-stressors is certainly more challenging but is critical to understanding the holistic impact of DDT+ within the marine environment.

- **Risk mitigation science:** The complexity of deep ocean DDT+ impacts will at first require leveraging existing information to make informed decisions to protect people while research examining the routes of exposure and impacts is underway. As it stands, limited available resources will require a hard look at what research is absolutely necessary to mitigate risk. Importantly, not all human exposure will be equal and differential vulnerability of human populations will be driven by factors including underlying health conditions and behaviors.

- **Risk communication science:** This is an increasingly important field of study as the complexity, breadth, and co-occurrence of environmental challenges accelerates. Examination of those best practices to communicate the actual risks of deep ocean DDT+ exposure and dispel inaccurate assumptions will be critical to communicate those specific exposure risks of local recreational, commercial, and subsistence users of the area. Beyond the actual messages conveyed, the messengers are also critically important. Leveraging those existing resources and trusted partners of vulnerable communities will be essential to develop culturally-relevant risk communication strategies. Several existing resources relevant to communicating DDT+ risk that were mentioned by the Workshop attendees are: EPA's new website [5] and the Fish Contamination Education Collaborative [40].

Synthesis: An Adaptive Model To Address Deep Ocean DDT+ Research Needs

Based on the Workshop discussions, subsequent listening sessions, and expert feedback, Sea Grant synthesized a schematic incorporating research categories across **Site Characterization**, **Ecological and Environmental Impacts,** and **Human Health and Well-Being**. This adaptive model of research needs (Figure 6), described in more detail below, provides a framework to guide a series of investments to address critical DDT+ research needs.

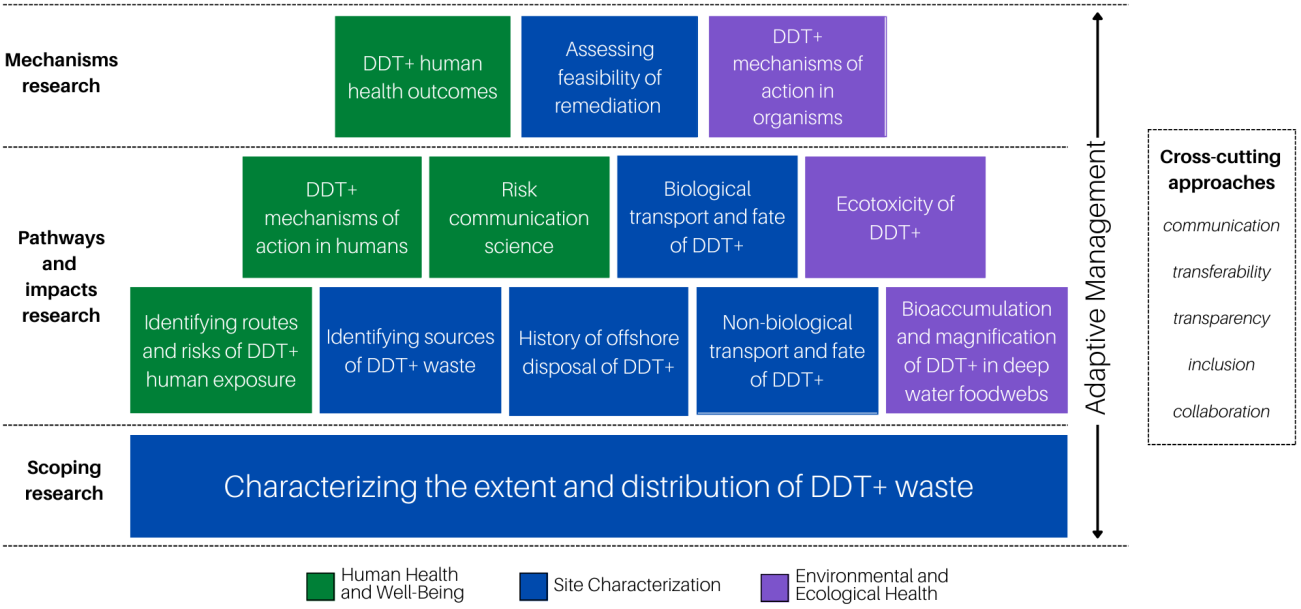


Figure 6. *Adaptive model of deep ocean DDT+ research needs in the Southern California Bight*

Navigating the Model

What Sea Grant heard from the diverse participants engaged in our Assessment was that the ultimate goal of any research should be to mitigate DDT+ risk to human and marine life. To do this, the first step is to understand what kind of DDT+ waste is currently there, where it currently is, and its potential for harm. Therefore, an adaptive model of research categories grounds *Characterizing the Extent and Distribution of DDT+ Waste* as a foundational research area for investment (i.e., the ***"Scoping Research"*** tier). Illuminating the scope of DDT+ contamination in the Southern California Bight will contextualize all other management-relevant research needs. Examination of DDT+ in present-day sediments, pore water, and the nearby water column will provide a snapshot of where DDT+ hotspots are located and potential pathways of exposure to be investigated. Biological sampling is also critical to the site characterization effort to link the deep sea DDT+ to the larger food web where humans and sentinel species might be exposed.

Establishing which archived and newly-collected biological samples can serve as sentinels of exposure over time will be essential to scoping the history and future exposure of human and marine life to DDT+.

Importantly, funders should keep in mind that this foundational research should be undertaken in service of supplying vital information to subsequent research which will shed light on environmental and human health risks. Not all research needs within the "*Scoping Research*" tier must be addressed before "*Pathways and Impacts Research*" may begin. Work associated with deep ocean toxicological research is challenging and can be expensive; thus the research community may tackle different aspects of the presented DDT+ research agenda based on available funding and existing expertise. Even so, Sea Grant heard repeatedly through the Assessment that future DDT+ findings, particularly addressing research needs in lower tiers, should inform subsequent research (i.e., an adaptive research agenda).

As DDT+ disposal sites are more fully characterized, investments in the ***"Pathways and Impacts Research"*** tier will become more impactful. The first row of research categories in this tier will expand our understanding of sources of DDT+ waste, how DDT+ is moving around the marine environment and accumulating in deep-water food webs, and how humans are coming into contact with DDT+. The second row of research categories build on previous findings to determine the biological extent of DDT+ contamination in marine and coastal ecosystems, assess toxicity to coastal organisms and humans (including co-stressors), and determine how to best communicate the risk of DDT+ exposure.

In the ***"Mechanisms Research"*** tier, the most challenging questions remain with regards to understanding the biological mechanisms by which DDT+ impacts the health of coastal organisms and humans, and whether it is feasible to remediate the deep ocean disposal sites without harming local ecosystems.

Research across all three themes will feed into adaptive management decisions regarding the deep ocean DDT+ disposal sites, including what actions will be taken to mitigate risk to marine organisms and coastal human communities. **Adaptive management** of deep ocean DDT+ waste (e.g., damage assessment, risk communication, and risk mitigation including potential remediation) requires adjusting strategies as more information is learned from all research categories and will be best approached through a grounding in foundational research discoveries.

Assessment participants echoed that cross-cutting approaches (e.g., communication, transferability, etc.) would be crucial to building a highly impactful and effective research agenda. Examples of how to integrate these cross-cutting approaches are discussed below in the *Immediate Actions to Advance DDT+ Research* section of this report.

Synthesis: Immediate Actions to Advance DDT+ Research

Through the Assessment, Sea Grant heard requests for several processes and approaches that are urgently needed in order to support more effective implementation of DDT+ research. We describe these in detail below.

Data Needs Assessment

There is substantial research on DDT and a few DDT-related compounds in nearshore marine environments, even within the Southern California Bight, that should be the starting point for new research that expands into DDT+ related compounds and deep ocean ecosystems. A data needs assessment would provide a better synthesis of what data is available documenting the extent and impacts of DDT+ within the Southern California Bight, and what new data is needed to address the research needs described in this document. Participants recommended that each research category presented in Figure 6 subsequently could be classified based on the amount of information known (low, medium, high), and the amount of time that would be expected to address a majority of research needs within the category.

Living Catalog of Archived Samples and DDT+ Research Programs

A database, catalog, or living platform is needed to support collaboration by tracking available archived samples, research cruises, or lab space and time. Many participants expressed concern about the lack of understanding of the true extent of archived deep ocean sediment and biological samples throughout California that could be leveraged for DDT+ research. Importantly, several researchers expressed concern that they would soon need to dispose of many of their samples due to space or storage issues, which could be an unfortunate (and expensive) loss of sample material that could be used by other researchers. Given that collecting deep sea samples is expensive and difficult, more coordinated and transparent logging of samples and cruises could facilitate more research on DDT+ in the near future. Participants specifically requested public tracking of samples that are needed, exist, or available for transfer. Further, there was interest in maintaining an index or listserv of current researchers working on DDT+ to facilitate collaboration as well as information about the facilities, equipment, and technology that these lab groups can leverage towards DDT+ efforts. DDT+ funding solicitations could build collaboration requirements into their requirements and provide spaces for prospective researchers to network to facilitate higher impact research expeditions.

Governance Framework and Connections with Research

While deep ocean disposal sites fall geographically within federal jurisdiction, potential transport of DDT+ into nearshore ecosystems make this a critical issue for California state agencies as well. Thus, navigating management of these disposal sites presents a governance challenge. For example, the remediation of DDT+ contaminated deep ocean sediments yielded interesting Workshop discussions in terms of associated research needs (see *Findings* section

of this report) and management considerations. Opinions varied regarding the feasibility and relative urgency of remediation of the deep sites in consideration of the suite of other research needs. It will be important to understand the true risk of DDT+ to human health in order to know if it is best to leave identified disposal sites undisturbed or if physical remediation is the best option for long-term human health and well-being. For example, many tribal communities would likely be restricted from their use of areas undergoing remediation, thus affecting their ability to engage in subsistence and recreation use of the area. What actions or inactions in the future will cause the least amount of additional harm to Southern California populations?

In this case, it could be beneficial to establish a governance framework (with inclusive public involvement) that enables regulatory agencies to collaborate and discuss whether remediation is necessary and, if so, determine the costs, impacts, and timelines to accomplish meaningful remedial action. Similarly, it would be useful to map the research needs described in this Assessment to the regulatory agencies who utilize that data to ensure coordination and communication between those entities and researchers. Attention and investment in understanding proper governance frameworks for regulatory agencies to collaborate on remediation and funding needs will be worthwhile.

Transferability and Standardization of Protocols

This Assessment focuses on deep ocean DDT+ disposal in the San Pedro and Santa Monica Basins because of the significant data gaps and challenges presented by deep ocean disposal sites, as well as the recent public and government focus on these areas outside of the U.S. EPA Montrose Superfund site. However, a number of the research needs herein are undoubtedly also relevant to understanding the existing extent and impacts of DDT+ within the Palos Verdes Shelf and understudied Consolidated Slip in Dominguez Channel. Thus future research would ideally be designed with transferability of methodologies or frameworks in mind for application to other DDT+ sites in California or beyond.

Standardization of protocols could also greatly assist in transferability of future DDT+ research. Participants highlighted a lack of consistent approaches to DDT+ sample collection, storage, processing, and data quality assurance and quality control (QA/QC) standards as existing barriers to collaboration across research labs and to the usability of some data for government decision-making. Participants echoed that there should be standardized data sharing and reporting and this should be communicated to all researchers working on DDT+ to make comparisons across studies easier. If this is not easily defined, perhaps a brief workshop among experts with facilitation is needed to agree upon state-standards to ensure efficient comparisons of results in the future.

Foster a Collaborative California Deep Ocean DDT+ Community of Practice

Several Workshop participants had not previously engaged with the deep ocean DDT+ issue, but had relevant, existing monitoring programs, laboratory technologies, and/or archived samples that could be applied. Collaboration (included as one of the cross-cutting approaches in Figure 6) and leveraging of research projects will be critical to address the breadth and complexity of DDT+ research needs.

For example, if well-planned, much could be gained from sharing existing samples or collecting samples for multiple projects during limited ship time. Participants identified the need for an ongoing "DDT+ Community of Practice" to expound on the identified research needs and support collaboration for more efficient and impactful research. Funders could leverage early funding investments by incentivizing collaboration through requirements in funding solicitations or by providing researcher networking opportunities.

Risk Communication

Clear and timely risk communication will be of great importance. Different geographies and communities will have varying levels of risk, and Assessment participants voiced that maintaining an environmental justice lens in DDT+ research and risk communication should be a high priority as historically under-resourced communities are at higher risk of compounded vulnerability to the health impacts of DDT+ exposure. It will be critical to leverage the extensive NGO and local community-based organizations to co-develop culturally relevant risk communication strategies and to consider social science-centered and environmental justice-focused strategies to develop effective risk communication campaigns with vulnerable communities.

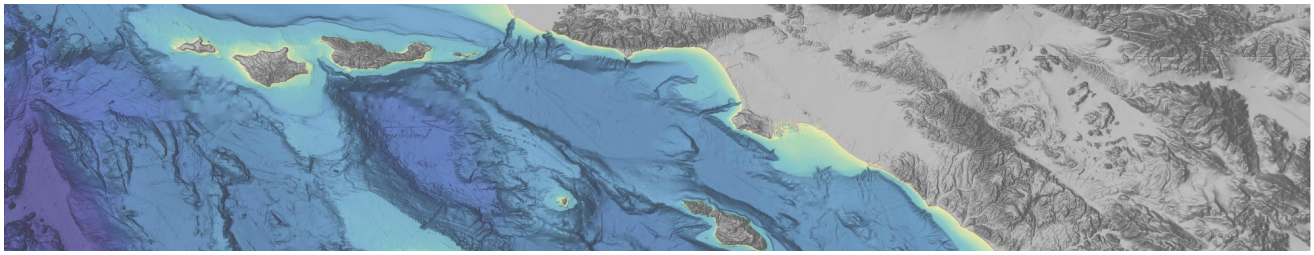
Inclusion and Transparency

One of the most repeated requests from all represented organizations was the need for greater inclusion and transparency around the deep ocean DDT+ issue. Thus “inclusion” and “transparency” are included in the cross-cutting approaches in Figure 6. Many participants in the Workshop expressed concern that past discussions and information about the deep ocean DDT+ (information, data, remediation, plans) had not been sufficiently inclusive of potentially impacted and interested community members. State, federal, and local collaboration will be essential to address these challenges in the future.

More specifically, participants expressed the need for:

- Research and communication efforts to meaningfully engage NGOs, communities of color, and vulnerable communities.
- Increased opportunities and involvement of a diversity of research institutions with the interest, capacity, and expertise to engage with DDT.
- Partnership with tribal communities who have not yet been meaningfully involved in the Southern California Bight DDT+ issue.

CONCLUSION



The disposal and subsequent impacts of DDT+ in the deep ocean environment raises numerous, intriguing scientific questions that are compiled in this Assessment. Yet the ultimate goal of this Assessment was to facilitate careful examination of which knowledge gaps are most critical and how future research could be approached to more efficiently and effectively understand the extent and impacts of deep ocean DDT+ disposal. Given the urgency of allocating state funding to this DDT+ issue in 2023, this Assessment — particularly the findings discussed in the *Deep Ocean DDT+ Research Agenda, Adaptive Model To Address Deep Ocean DDT+ Research Needs,* and *Immediate Actions to Advance DDT+ Research* sections — can help focus and direct funding to the most imperative and impactful research needs.

Ultimately, the deep ocean disposal of DDT+ has significant implications for those federal and California state natural resource agencies with responsibility for managing local coastal resources. Workshop discussions had a strong focus on ensuring the **management relevance of research investments** due to the expense and complexity of associated research methodologies as well as **public urgency to understand existing risk and implement appropriate adaptive strategies**. It is clear that maintaining strong relationships between natural resources agencies and researchers will help ensure that research is being conducted that is standardized and executed in ways that can directly inform management decisions.

Despite Southern California's complicated history with DDT+, this moment presents an opportunity for a new chapter written by exceptionally collaborative, innovative, and efficient research driving meaningful management decisions.

Overall, this inclusive and community-driven Assessment aims to empower funding agencies, researchers, and communities with a holistic perspective of critical DDT+ research needs to address in the immediate future. Continued engagement of the scientific, management, tribal, industry, and diverse, local communities will be integral to an effective transition to implementing these priority research areas. Despite Southern California's complicated history with DDT+, this moment presents an opportunity for a new chapter written by exceptionally collaborative, innovative, and efficient research driving meaningful management decisions.

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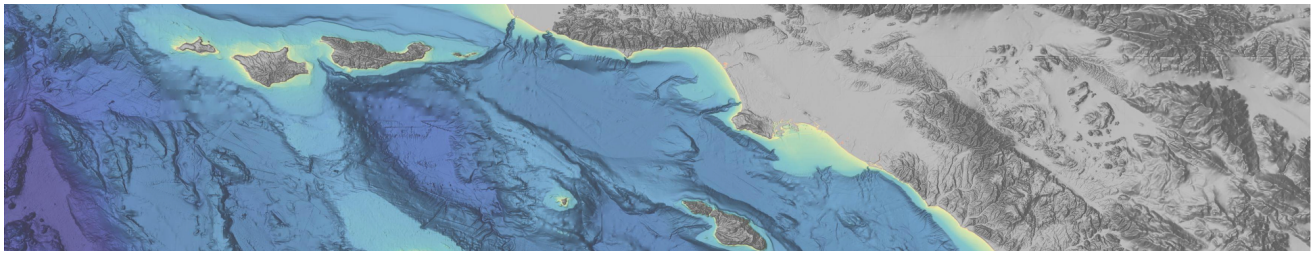

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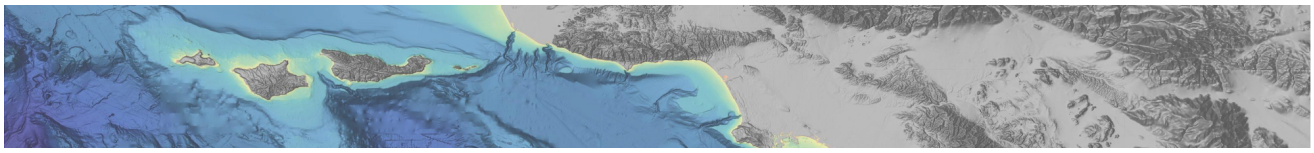
APPENDICES



Appendix A: California DDT+ Research Needs Workshop Organizers, Facilitators, Notetakers, Advisory Committee, and Attendees

Organizers:

Amalia Aruda Almada, USC Sea Grant
Lian Guo, California Sea Grant
Amulya Jasti, USC Student
Allegra La Ferr, California State Sea Grant Fellow

Facilitators:

Linda Chilton, USC Sea Grant
Phyllis Grifman, USC Sea Grant
Maria Madrigal, USC Sea Grant
Leah Shore, USC Sea Grant
Charlotte Stevenson, USC Sea Grant
Kevin Travis, California Ocean Science Trust
Madelyn Wampler, California Sea Grant

Notetakers:

Aaron Angel, California State Sea Grant Fellow
Emilia Antrim-Caldari, California Ocean Science Trust
Alex Bevan, California State Sea Grant Fellow
Montana Denton, USC Student
Emma Johnson, USC Student
Samantha Kwan, USC Student
Isabelle Martinez-Cartwright, USC Student
Kimi Rogers, California State Sea Grant Fellow

Advisory Committee:

Lihini Aluwihare, Scripps Institution of Oceanography
Allan Chartrand, Chartrand Environmental LLC
Gabrielle Crowe, Gabrielino-Shoshone Nation/Ballona Wetlands Land Trust
Michael Quill, Los Angeles Waterkeeper
David Valentine, University of California, Santa Barbara
Steve Weisberg, Southern California Coastal Water Research Project (SCCWRP)

We would like to acknowledge the critical contributions of our organizers, facilitators, notetakers, and Advisory Committee in the development of the Workshop.

Participant Affiliations:

Ballona Wetlands Land Trust
Broad Reach Fund
California Department of Fish and Wildlife
California Department of Toxic Substances Control
California Cooperative Oceanic Fisheries Investigations
California Ocean Protection Council
California Office of Environmental Health Hazard Assessment
California Sea Urchin Divers Network
Catalina Island Conservancy
Center for Biological Diversity
Chartrand Environmental, LLC
City of Los Angeles, Environmental Monitoring Division
Coastal Conservation Association California
Creek Lands Conservation
Gabrielino-Shoshone Nation
Heal the Bay
Los Angeles Regional Water Quality Control Board
Los Angeles Waterkeeper
Marine Mammal Center
Marine Mammal Commission
Monterey Bay Aquarium Research Institute
National Institute of Standards and Technology
Naval Information Warfare Center Pacific
NOAA
NOAA, Southwest Fisheries Science Center
NOAA, National Centers for Coastal Ocean Science
NOAA, Office of Response and Restoration
San Diego State University
San Diego State University Research Foundation
San Diego State University School of Public Health
San Diego Zoo Wildlife Alliance
Santa Monica Bay Restoration Commission
Southern California Coastal Water Research Project
Southern California Coastal Ocean Observing System
Surfrider Foundation
The Ocean Foundation
U.S. Environmental Protection Agency
U.S. Food and Drug Administration
University of California, Davis, School of Veterinary Medicine
University of California, Los Angeles
University of California, San Diego, Scripps Institute of Oceanography
University of California, Santa Barbara
University of Southern California, Wrigley Institute of Environmental Studies
University of Southern California, Keck School of Medicine
U.S. Senate
Western Washington University
Wood Environment & Infrastructure Solutions

Appendix B: C5 Conference Agenda and Speakers, May 16-17, 2022

Session 1: Certainties and Uncertainties of a Historical Legacy

- **Allan Chartrand**, Chartrand Environmental LLC, Identifying ecological effects of legacy DDT wastes ocean dumped into Southern California Bight basins
- **David Valentine**, University of California, Santa Barbara, Sloppy dumping of DDT waste off California: there is a lot we don't know

Session 2: Environmental Effects of Organohalogens

- **Eunha Hoh**, San Diego State University, DDX Accumulation in Regional Marine Mammals and Wildlife and Their Health Impacts
- **Frances Gulland**, Marine Mammal Commission, Health effects of organochlorines on California sea lions
- **Kari Sant**, San Diego State University, Aquatic toxicological assessment of the emerging DDT co-contaminants

Session 3: Health Effects and Epidemiology

- **Howard Hu**, Keck School of Medicine, University of Southern California, Long-lived Endocrine Disrupting Chemicals: Update on the Epidemiology
- **Michele La Merrill**, University of California, Davis, Health effects of DDX+: rodents and humans

Lightning Talks

- **Lisa Levin**, Scripps Institution of Oceanography (pre-recorded), Levin-Neira studies of DDT-associated impacts on macrobenthos in San Pedro Basin
- **Chris Stransky**, Wood Environment & Infrastructure, Preliminary Toxicity Assessment of Deep-Sea Sediments in the Vicinity of DDT Waste Barrels off Catalina Island, southern California
- **Nathan Dodder**, San Diego State University, The Historical Trend of DDX in California Marine Mammals
- **Kelli Hackney**, Intertox, Ongoing investigations concerning the reproductive effects of DDE in coastal California condors
- **Saulo Muller Soares**, Scripps Institution of Oceanography, Currents within San Pedro basin from shipboard ADCP data of opportunity
- **Ken Schiff**, Southern California Coastal Water Research Project Authority, Bightwide Regional Monitoring of DDT

Session 4: Environmental Processes

- **James McWilliams**, University of California, Los Angeles, Circulation and Dispersal in California's Borderland Basins
- **J. Samuel Arey**, Oleolytics LLC, Testing the possible histories of DDT in offshore sediments with fate modeling
- **Tina Treude**, University of California, Los Angeles, Microbial pathways of organic matter/pollutant degradation in sediments

Day 2 Opening Talks

- **John Chesnutt and Judy Huang**, Environmental Protection Agency, Region 9, Federal/State Ocean Disposal Workgroup: Progress and Challenges
- **Mark Gold**, California Natural Resources Agency, Ocean Protection Council, State Perspective on Coastal DDT Contamination off Los Angeles County

Pitches

- **Mara Freilich**, Scripps Institution of Oceanography, Transport pathways for redistribution of DDT by ocean currents in the San Pedro basin and regional connectivity
- **Will Berelson**, University of Southern California, Changes in sedimentation
- **Erin Satterthwaite**, California Sea Grant, Scripps Institution of Oceanography, Assessing the transfer of DDT+ through the pelagic marine food web
- **Charles Wong**, Southern California Coastal Water Research Project Authority, Palos Verdes Shelf DDT Revisited
- **Angelica Rodriguez**, Naval Information Warfare Center Pacific, Benthic Enabled Autonomous Collaborative Operations Notification System (BEACONS)
- **Katherine Pease**, Heal the Bay, Protecting Public Health and Advocacy
- **Amalia Almada**, University of Southern California Sea Grant Program, Upcoming Sea Grant "California DDT+ Research Needs Assessment" Workshop

Appendix C: Workshop Overview and Agenda

California Stakeholder DDT+ Research Needs Workshop

Overview

Meeting Purpose and Objectives

This 2-day interactive workshop will gather perspectives from diverse California stakeholders regarding those critical research needs emerging from the disposal of DDT and associated chemicals (DDT+) in the deep ocean waters of the San Pedro Channel. The workshop discussion will feed into the development of a California Stakeholder DDT+ Research Needs Assessment, further supported by a broadly administered stakeholder survey and synthesis of existing DDT+ assessment reports. The California DDT+ Research Needs Assessment Report will ultimately provide a framework for meaningful and timely research investment into DDT+ impacts on California coastal resources and the communities who use them.

Participants in this workshop will:

- Gain broad context of the history of DDT+ contamination in Southern California and its implications for human and environmental health;
- Share their professional perspective on those DDT+ research needs that are most critical to their organization or sector;
- Provide input to characterize the level of effort required relative to the impact of different lines of DDT+ research

Note that this workshop will not focus on advocating any responsibility, litigation, or disclosure of internal information from entities or other workshop attendees and instead will focus on discussion of critical research needs.

Workshop Preparation

Participants are asked to review a briefing document that will be sent to all registrants the week prior to the workshop.

Community Guidelines

- Listen and participate with respect for the diversity of perspectives, viewpoints, and identities of participants.
- Ensure all verbal and written comments are constructive to the purpose of the workshop.
- Participate authentically and be fully present. We ask that you manage your technology respectfully.
- Note that there will be additional opportunities after the workshop to provide input on the Research Needs Assessment Report.

*Note: Throughout the workshop, including within and between breakout rooms, you will be asked to share your thoughts on **Padlet** (**padlet.com**). Padlet is a virtual collaborative workspace where you can anonymously create text posts to send input to our researchers. No account is required for the platform. If your affiliated organization prevents you from using Padlet, breakout sessions will have designated notetakers to record your input.*

Appendix C (con't): Workshop Overview and Agenda

California Stakeholder DDT+ Research Needs Workshop

Agenda

Sea Grant University of Southern California Sea Grant California

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01 MONDAY, JULY 18, 2022: *10AM - 1PM PT*
Zoom link: https://ucsd.zoom.us/j/97843419459

Welcome Remarks

- Workshop overview, community guidelines, participant roles
- Welcome from the University of Southern California Sea Grant, California Sea Grant, and National Sea Grant Office Leadership

Panel Discussion

- Overview of current understanding of the extent, impacts, and management of ocean disposal of DDT+ in the San Pedro Channel
- Speakers: Gabrielle Crowe (Gabrielino-Shoshone Tribal Council of Southern California), Dave Valentine (University of California Santa Barbara), Eunha Hoh (San Diego State University), Mark Gold (Ocean Protection Council)

Breakout Discussion #1

- (*25 mins*) Introductions to assigned breakout group, exchange reflections on panel discussion and briefing document

15 min break

Breakout Discussion #2

- (45 *mins*) Facilitated activity to expand compiled themes of DDT research needs and exchange perspectives on those needs most critical to the represented stakeholders

Day 1 Wrap-up

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02 TUESDAY, JULY 19, 2022: *10AM - 1PM PT*
Zoom link: https://ucsd.zoom.us/j/97843419459

Welcome Remarks

- Recap of day 1 and overview of day 2
- Keynote: Allan Chartrand

Breakout Discussion #3

- (*60 mins*) Facilitated activity to characterize the level of effort required relative to the impact of different lines of DDT+ research

15 min break

Breakout Discussion #4

- (*25 mins*) Facilitated discussion to optimize the approach and content of the *California Stakeholder Research Needs Assessment Report*

Wrap up

Appendix D: California DDT+ Research Needs Workshop Speakers

Workshop Day 1, July 18, 2022

Brooke Carney: Brooke Carney is the Communications Director for Sea Grant and serves as the Program Officer for Alaska, Oregon, and Washington Sea Grant programs as well as for the National Sea Grant Library. Brooke is also the NSGO liaison to the Sea Grant Educators Network (SGEN), and serves as the lead for Diversity, Equity, and Inclusion (DEI); Traditional and Local Knowledge (TLK); and facilitation topical areas. She holds master's degrees in Biology and Public Administration and has focused her career on both the internal and external communications of science-based programs at the local, state, and federal levels.

Gabrielle Crowe: Gabrielle Crowe is a member of the Ballona Wetlands Land Trust Board and is Vice Chair of the Gabrielino-Shoshone Tribal Council of Southern California. Gabrielle Crowe has immense experience and passion for outdoor and environmental education. Gabrielle was the lead Naturalist at the Mary Vagle Nature Center and worked at the Ocean Institute as the lead Science Instructor and Outdoor Education Coordinator, taking many students snorkeling and hiking at Catalina Island. It is Gabrielle's life work to empower Southern Californians to be environmental stewards and allies to Indigenous people, the first stewards of this land.

David Valentine: David Valentine holds the Norris Presidential Endowed Chair in Earth Science, is the founding director of the Marine Science program in the College of Creative Studies, and is a Distinguished Professor of Geochemistry and Microbiology, at UC Santa Barbara. Professor Valentine's research interests focus on the interaction of microbes and chemicals - how the smallest living beings impact Earth's environment and how the environment structures the ecology and evolution of the microbes. His research team conducted several ROV and AUV surveys around the deep-water ocean basins which assisted in documenting DDT+ waste and associated microbial communities. Most recently, he organized the California Coastal Chloro Contamination Conference which convened active Southern California DDT+ researchers to share their findings and begin discussions about research needs that will be built on in this workshop.

Mark Gold: As the former Executive Director of OPC and the Deputy Secretary for Ocean and Coastal Policy for the California Natural Resources Agency, Dr. Mark Gold served as a key advisor to the Governor and the Secretary of Natural Resources, and directed policy, scientific research and critical partnerships to increase protection of coastal and ocean resources in California. Prior to his appointment, he was the UCLA Associate Vice Chancellor for Environment and Sustainability, where he led their Sustainable Los Angeles Grand Challenge effort. Prior to UCLA, Mark was the first hire at Heal the Bay, where he served as their President for 18 years. During that time, he worked on ocean and coastal legislation and policy, stormwater, watershed management, and marine conservation and coastal restoration issues, projects and programs. Over the course of his career, his research focused on beach water quality and health risks, as well as sustainable water resources management.

Eunha Hoh: Eunha Hoh is a Professor and Division Head of the Department of Environmental Health in the School of Public Health at San Diego State University. Her 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. She has 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.

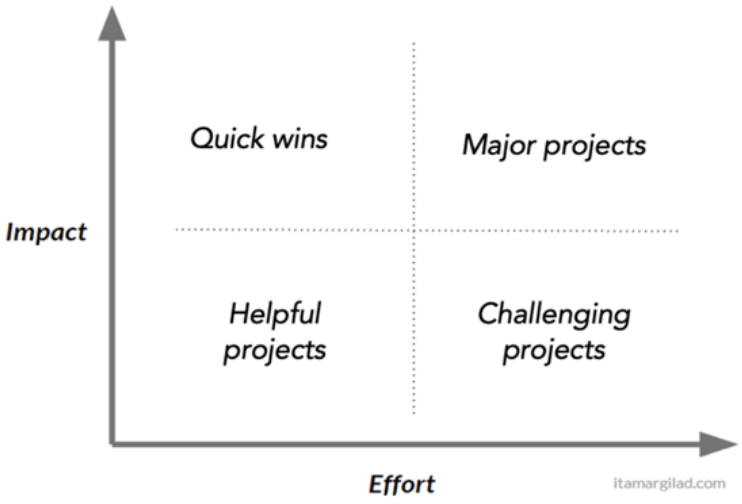
Workshop Day 2, July 19, 2022

Allan Chartrand: Allan Chartrand is a career environmental scientist, toxicologist, and risk assessor. He was Board-certified by the American Board of Toxicology, and is a former water quality scientist for California's Los Angeles Regional Water Quality Control Board (LARWQCB). He was the senior author on the original "Ocean Dumping of DDT" report issued by the agency in 1985, which led to extensive public attention and investigation of the nature of DDT in these deep-water basins. He was the principal investigator for the follow-up DDT ocean dumping investigation, completed in 1987. He also provided expert testimony on the 2000 DDT trial against Montrose Chemical and other parties, and most recently served as principal investigator and senior author on the just-released report "Continuing Ecological Effects of Deepwater Ocean Dumping of DDT Wastes into the Southern California Bight."

Appendix E: Example of Workshop "Impact v Effort" Activity

Goal: to have a discussion about the level of effort required to address a research need compared to the level of impact it will have in understanding the extent and impacts of DDT+ dumping

Impact:
Informs decision-making, enables other research or activities to occur



Effort:
Funding, personnel, time

Sea Grant
University of Southern California

Sea Grant
California