Improving access to fish consumption advisories and maintaining confidence in California's healthy seafood products

Proposers & Clients:

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a. Objectives

Recreational fisheries along the California coast produce billions in derived economic benefit annually, however, the recent rediscovery of a vast barrel field of dichlorodiphenyltrichloroethane (DDT)-laced sludge off the coast of southern California (Xia 2020) has captured the attention of the public and raised concerns regarding consumption of contaminated seafood. The growing evidence of extensive toxin dumping in Southern California may cause consumers to shy away from the region's seafood products. Through this project we aim to help restore consumer confidence in California's healthy seafood products by:

1. Developing spatiotemporal statistical models to predict DDT concentrations in sport fish across Southern California.
2. Creating a public-facing online application to visualize predicted DDT concentrations for specific fish species and locations of capture, aiding the general public in accessing and applying fish consumption advisories across the region.

b. Significance

DDT is a pollutant that is resistant to degradation (Blais 2005), resulting in its accumulation in sediments, bioaccumulation in organisms, and biomagnification through food webs (Kidd et al. 1998, 2001). DDT exposure has been linked to increased risks of cancer, premature births, developmental abnormalities, and neurological diseases in humans and animals (Nicklisch et al. 2016). Furthermore, the impacts of exposure can last generations; a recent study found adverse health effects in women whose maternal grandmothers were exposed to DDT (Cirillo et al. 2021).

Within Southern California from 1947-1971, the largest producer of DDT in the world, Montrose Chemical Corporation, discharged its industrial waste both through the Los Angeles County wastewater treatment plant, which was deposited nearshore on the Palos Verdes Shelf (PVS), and via ships that transported and dumped barrels in deeper waters (Venkatesan et al. 1996, Zeng and Venkatesan 1999, Kivenson et al. 2019). The PVS was designated as an EPA Superfund Site, however, the presence of offshore dumping was only recently rediscovered and the extent and impact of this contamination are not well understood (Kivenson et al. 2019, Xia 2020). Due to the uneven legacy of dumping, a gradient of sediment DDT contamination spanning several orders of magnitude exists across Southern California (Zeng and Venkatesan 1999, Schiff et al. 2016) and concentrations are high enough to endanger both wildlife, such as marine mammals (Mackintosh et al. 2016, Gulland et al. 2020) and the endangered California Condor (Stack et al. 2022), and human consumers of seafood products.

Given the overall high contaminant concentrations and uneven distribution, it is critical that localized consumption advisories are widely available to fish consumers. Fish consumption advisories play a crucial role in safeguarding public health by providing essential information about the safety of consuming fish from specific waters, helping individuals make informed choices to minimize their exposure to harmful contaminants.

c. Background

In 2021, Scripps Institution of Oceanography was awarded $5.6 million in spending directed by Senators Dianne Feinstein and Alex Padilla to study the human and ecological impacts of the recently discovered deep DDT dumpsite. As part of this effort, researchers assembled a comprehensive database of

previously collected fish and sediment contaminant monitoring data. Initial analysis of this data indicates that fish DDT concentrations vary across small spatial scales and display a strong correlation with sediment DDT concentrations. Moreover, these concentrations are influenced by ecological factors such as species, trophic interactions, and habitat preferences. Modeling efforts showed high out-of-sample predictability, indicating that results could be used to predict localized risk to consumers.

Presently, the California Environmental Protection Agency Office of Environmental Health Hazard Assessment (OEHHA) has a general statewide consumption advisory for coastal locations and a limited number of site-specific consumption advisories, with only a subset of commonly-caught species considered in these advisories. The proposed application will provide an easily accessible and reliable source of information that allows the public to make informed decisions about their seafood choices. Overall, the development and deployment of this tool will aid in efforts to preserve the economic value of California's marine resources by guiding fish consumption practices that generate safe and healthy seafood products. By offering more detailed and accurate seafood consumption advice, this application will restore consumer confidence, promote healthy fishing practices, and ensure the continued enjoyment of Southern California's coastal seafood offerings.

d. Equity

Recreational fishing is widespread in Southern California, with an estimated 10 million or more fish caught each year by recreational fishers. Urban anglers within the region are a heterogenous and often socioeconomically vulnerable population (Stevenson et al. 2012) who supplement their access to food by using a critical natural resource in a predominantly urban context (Quimby et al. 2020, Marjadi et al. 2021). This project will leverage existing information to mitigate risks of consuming contaminated seafood. This is particularly important for vulnerable human populations.

e. Data

- Rasters of sediment DDT concentrations across the Southern California Bight from 2003-2018. Data was collected by the Southern California Bight Regional Monitoring Program and rasters were processed by Lillian McGill. Data is available here: https://github.com/lmcgill/FishDDTApp/tree/main/data/sediment_rasters.
- A database of fish DDT monitoring data collected within the Southern California Bight. Fish tissue contaminant data was aggregated from eight different surveys across Southern California collected between 1998 and 2021 (Table S1). Data is available here: https://github.com/lmcgill/FishDDTApp/blob/main/data/fish_data/totalDDT_fish_SouthernCA.csv.
- A database of species life history characteristics. Data is available here: https://github.com/lmcgill/FishDDTApp/blob/main/data/fish_data/fish_life_history.csv.

f. Computational tools & needs

- We anticipate that most programming will occur in R.
- Computational tools will include advanced statistical methods such as bayesian modeling, spatiotemporal regression, and mixed-effects regression. Support will be provided by the clients in the preparation and running of these models throughout the project lifespan.
- The online application will be developed in RShiny and hosted by the California Cooperative

Oceanic Fisheries Investigation on the calcofi.io domain. CalCOFI already hosts numerous open-source online applications and is well equipped to provide long-term support post-project completion.

g. Possible approaches

The clients will will work closely with the MEDS capstone student group to develop an approach for meeting the deliverables and objectives, which may include the following steps:

Data analysis

Students will process sediment DDT concentration rasters to extract the corresponding sediment DDT values at each fish's capture location within our database. Students will then develop multiple candidate models to predict fish DDT concentrations using covariates such as sediment DDT concentration at the location of fish capture, year of capture, and fish life-history characteristics such as diet, habitat, and species. Model selection will be used to identify the best-fit model that maximizes out-of-sample prediction performance. Students will use predictions from the best-fit model to derive spatially continuous, species-specific estimates of total DDT in sport fish across Southern California.

Data visualization & Web platform development

Students will integrate DDT estimates with Advisory Tissue Levels (ATLs) for DDT (Table S2) and existing consumption advisories that encompass multiple contaminants (Figure S2) to develop a user-friendly online application. The online application will offer predictions of DDT concentrations for unmeasured species and locations and the probabilistic estimation of a particular fish exceeding consumption thresholds. We anticipate that the students will produce an R Shiny dashboard application (or other interactive application), with interactive maps (e.g., using Leaflet) and plots (e.g., using Plotly). The application will allow users to input the location of capture, species, and consumer demographic information to receive probabilistic estimates of exceeding safe consumption thresholds. See Figure S1 for an example layout of an RShiny App.

h. Deliverables

1. Spatial predictions of DDT in sport fish across Southern California from optimized models.
2. Development of an online application that displays predicted DDT concentrations for an angler's catch in relation to California consumption advisories.
3. Development of a reproducible workflow to ingest new monitoring data into the model and application as it becomes available (stretch goal).

i. Audience

The audience will be California-based recreational anglers interested in accessing the latest consumption recommendations for their catch. We anticipate that anglers would pull up the application after catching a fish, to determine if the specific species and location combination fall within “safe to eat” thresholds.

Supporting Materials

a. Citations

Blais, J. M. 2005. Biogeochemistry of persistent bioaccumulative toxicants: processes affecting the transport of contaminants to remote areas. Canadian Journal of Fisheries and Aquatic Sciences 62:236–243.

Cirillo, P. M., M. A. La Merrill, N. Y. Krigbaum, and B. A. Cohn. 2021. Grandmaternal Perinatal Serum DDT in Relation to Granddaughter Early Menarche and Adult Obesity: Three Generations in the Child Health and Development Studies Cohort. Cancer Epidemiology, Biomarkers & Prevention 30:1480–1488.

Gulland, F. M. D., A. J. Hall, G. M. Ylitalo, K. M. Colegrove, T. Norris, P. J. Duignan, B. Halaska, K. Acevedo Whitehouse, L. J. Lowenstine, A. C. Deming, and T. K. Rowles. 2020. Persistent Contaminants and Herpesvirus OtHV1 Are Positively Associated With Cancer in Wild California Sea Lions (Zalophus californianus). Frontiers in Marine Science 7:602565.

Kidd, K. A., H. A. Bootsma, R. H. Hesslein, D. C. G. Muir, and R. E. Hecky. 2001. Biomagnification of DDT through the Benthic and Pelagic Food Webs of Lake Malawi, East Africa: Importance of Trophic Level and Carbon Source. Environmental Science & Technology 35:14–20.

Kidd, K. A., R. H. Hesslein, B. J. Ross, K. Koczanski, G. R. Stephens, and D. C. G. Muir. 1998. Bioaccumulation of organochlorines through a remote freshwater food web in the Canadian Arctic. Environmental Pollution 102:91–103.

Kivenson, V., K. L. Lemkau, O. Pizarro, D. R. Yoerger, C. Kaiser, R. K. Nelson, C. Carmichael, B. G. Paul, C. M. Reddy, and D. L. Valentine. 2019. Ocean Dumping of Containerized DDT Waste Was a Sloppy Process. Environmental Science & Technology 53:2971–2980.

Klasing, S., and R. Brodberg. 2008. Development of Fish Contaminant Goals and Advisory Tissue Levels for Common Contaminants in California Sport Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene. California Office of Health Hazards Assessment, Sacramento, CA.

Mackintosh, S. A., N. G. Dodder, N. J. Shaul, L. I. Aluwihare, K. A. Maruya, S. J. Chivers, K. Danil, D. W. Weller, and E. Hoh. 2016. Newly Identified DDT-Related Compounds Accumulating in Southern California Bottlenose Dolphins. Environmental Science & Technology 50:12129–12137.

Marjadi, M. N., L. Drakopulos, L. W. Guo, J. Z. Koehn, S. V. Panchang, and D. Robertson. 2021. Negative socio-environmental feedback loop may foster inequality for urban marine subsistence fishers. Environmental Science & Policy 121:68–77.

McLaughlin, K., J. Davis, A. Bonnema, B. Du, G. Ichikawa, W. Jakl, W. Heim, and K. Schiff. 2021. Regional assessment of contaminant bioaccumulation in sport fish tissue in the Southern California Bight, USA. Marine Pollution Bulletin 172:112798.

Nicklisch, S. C. T., S. D. Rees, A. P. McGrath, T. Gökirmak, L. T. Bonito, L. M. Vermeer, C. Cregger, G. Loewen, S. Sandin, G. Chang, and A. Hamdoun. 2016. Global marine pollutants inhibit P-glycoprotein: Environmental levels, inhibitory effects, and cocrystal structure. Science Advances 2:e1600001.

Quimby, B., S. Es. Crook, K. M. Miller, J. Ruiz, and D. Lopez-Carr. 2020. Identifying, defining and exploring angling as urban subsistence: Pier fishing in Santa Barbara, California. Marine Policy 121:104197.

Schiff, K., D. Greenstein, N. Dodder, and D. J. Gillett. 2016. Southern California Bight regional monitoring. Regional Studies in Marine Science 4:34–46.

Stack, M. E., J. M. Cossaboon, C. W. Tubbs, L. I. Vilchis, R. G. Felton, J. L. Johnson, K. Danil, G. Heckel, E. Hoh, and N. G. Dodder. 2022. Assessing Marine Endocrine-Disrupting Chemicals in the Critically Endangered California Condor: Implications for Reintroduction to Coastal Environments. Environmental Science & Technology 56:7800–7809.

Stevenson, C., S. A. Sikich, and M. Gold. 2012. Engaging Los Angeles County subsistence anglers in the California marine protected area planning process. Marine Policy 36:559–563.

Venkatesan, M. I., G. E. Greene, E. Ruth, and A. B. Chartrand. 1996. DDTs and dumpsite in the Santa Monica Basin, California. Science of The Total Environment 179:61–71.

Xia, R. 2020, October 25. How the waters off Catalina became a DDT dumping ground. Los Angeles Times.

Zeng, E. Y., and M. I. Venkatesan. 1999. Dispersion of sediment DDTs in the coastal ocean off southern California. Science of The Total Environment 229:195–208.

b. Budget and justification

We do not anticipate needing any additional funding for this project. All data are freely available, and objectives can be completed with open-source software. We anticipate that the $250 provided by the Bren School will be sufficient.

c. Client Letter of Support

MEDS Project Selection Committee
Bren School of Environmental Science & Management
2400 Bren Hall
UC Santa Barbara, CA 93106

Dear MEDS Project Selection Committee,

We wholeheartedly endorse the MEDS Project Proposal "Improving access to fish consumption advisories and maintaining confidence in California's healthy seafood products". We are writing this letter on behalf of the entire client team, which includes Drs. Brice Semmens, Erin Satterthwaite, and Lillian McGill.

This project will leverage underutilized monitoring data and advanced statistical models to create an online application that will provide an easily accessible and reliable source of information that allows the public to make informed decisions about their seafood choices. Integrating spatiotemporal model output with consumption advice for DDT will improve the resolution and accessibility of consumption advisories across Southern California. This project not only addresses the critical need for safeguarding public health, the environment, and the economy in Southern California, but also places a strong emphasis on equity by mitigating risks for socioeconomically vulnerable populations who heavily rely on seafood as a food source.

As the clients on this project, we can commit to regular consultation and supervision throughout the duration of the project with a minimum of bi-weekly meetings until June 2024 to ensure consistent communication and collaboration. We don't not anticipate needing additional funding to complete this project. Continued support and maintenance for the RShiny application will be provided by the California Cooperative Oceanic Fisheries Investigation on the calcofi.io domain. CalCOFI already hosts numerous open-source online applications and is well equipped to provide long-term support post-project completion.

All of the data necessary to complete this project are already available within the public GitHub repository listed in the proposal: https://github.com/lmcgill/FishDDTApp. We will answer any relevant questions and do our best to provide any additional data as needed.

Thank you for your consideration of this project and please let us know if there is any additional information we can provide.

Thank you,
Lillian McGill

Supplementary Material

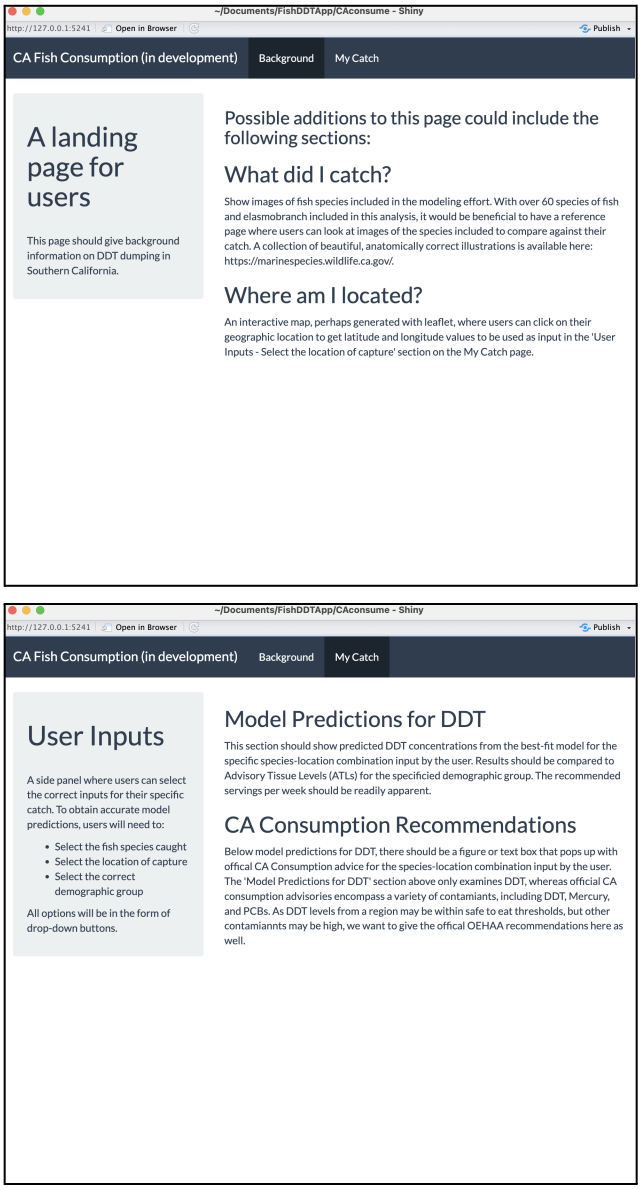
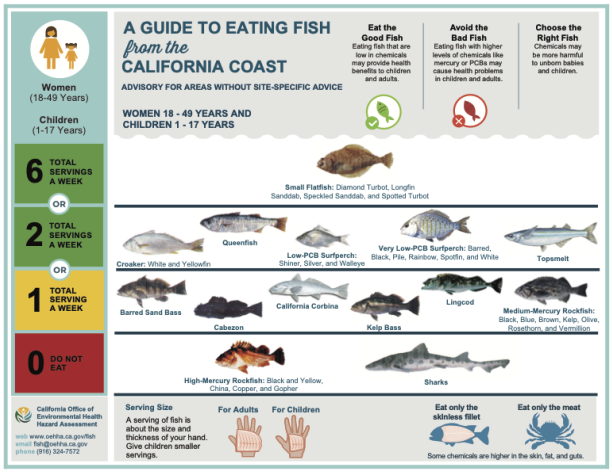


Figure S1. An example layout for a RShiny Application. Students are welcome to use this as a template or develop an alternative structure.



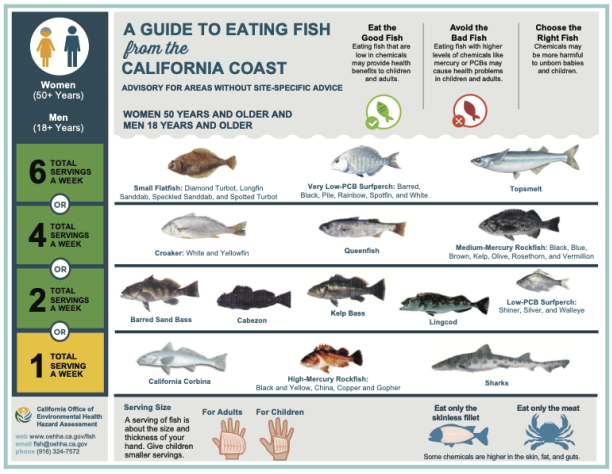


Figure S2. OEHHA statewide advisory posters for eating fish from California coastal locations without site-specific advice. Posters were downloaded from the OEHHA website. Separate advisories are available for the following locations: Elkhorn Slough, Ventura Harbor to Santa Monica Pier, Santa Monica Beach south of Santa Monica Pier to Seal Beach Pier, South of Seal Beach Pier to San Mateo Point, Mission Bay, and San Diego Bay. All advisory posters are available at this link.

Table S1. Data provenance for sediment and fish contaminant monitoring. SCB is an abbreviation for the Southern California Bight.

Data source	Data type	Sample#	Spatial extent	Temporal extent	Data origin
Southern California Bight Regional Monitoring Program	Sediment chemistry, composition, and organic matter	1271	Point Conception, CA to US-Mexico border	2003, 2008, 2013, 2018	http://sccwrp.org/Data/SearchAndMapData/DataCatalog.aspx
SWAMP Statewide Coastal Screening Survey	Fish composite chemistry, length, sex, and species	142	Coastal CA, filtered to only SCB	2009-2010, 2018-2019	https://www.waterboards.ca.gov/water_issues/programs/swamp/coast_study.html
SWAMP Coastal Fish Contamination Program	Fish composite chemistry, composite number, length, sex, and species	305	Coastal CA, filtered to only SCB	Annually from 1998-2003	https://www.waterboards.ca.gov/water_issues/programs/swamp/coast_study.html
Jarvis et al. 2007	Fish composite chemistry, composite number, length, and species	88	Pelagic SCB	2003-2004	Pers. Comm. Dr. Erica Mason (Jarvis)
McLaughlin et al. 2021	Fish composite chemistry, composite number, length, and species	150	SCB	2009-2010, 2018-2019	Pers. Comm. Dr. Karen McLaughlin
Southern California Coastal Marine Fish Contaminants Survey	Fish composite chemistry, composite number, length, and species	69	Palos Verdes, Santa Monica Bay, and San Pedro Bay regions	2002-2004	https://19january2017snapshot.epa.gov/www3/region9/superfund/pvshelf/pdf/montrose_report.pdf
LA County Sanitation District Local Trends Assessment	Fish composite chemistry, composite number, length, and species	124	Adjacent to Palos Verdes	Annually from 2006-2021	Pers. Comm. Shelly Walther

LA County Sanitation District Seafood Safety Assessment	Fish composite chemistry, composite number, length, and species	80	Adjacent to Palos Verdes	2006, 2008, 2010, 2012, 2014, 2016, 2018, 2020	Pers. Comm. Shelly Walther
City of San Diego POTW Monitoring	Fish composite chemistry, composite number, and species	134	Adjacent to Point Loma and South Bay outfall	Annually from 2001-2022	https://www.sandiego.gov/public-utilities/sustainability/ocean-monitoring/reports/annual-report-archives

Table S2. Fish Advisory Tissue Levels (ATLs) for selected contaminants based on carcinogenic or non-carcinogenic risk using an 8-ounce serving size per week (prior to cooking). Values are in ng/g (PPB), wet weight. Thresholds for concern based on an assessment of human health risk by Klasing and Brodberg (2008, updated 2017). Fish Contaminant Goals (FCGs) are estimates of contaminant levels in fish that pose no significant health risk to individuals consuming sport fish at a standard consumption rate of eight ounces per week (32 g/day), prior to cooking, over a lifetime. Table is adapted from McLaughlin et al. (2021).

Contaminant	FCG	ATLs for the Number of 8-oz servings per week (in ng/g)							
		7	6	5	4	3	2	1	Do Not Consume
Mercury (women 18-49; children 1-17)	220	≤31	31-36	36-44	44-55	55-70	70-150	150-440	>440
Mercury (women > 49; men)		≤94	94-109	109-130	130-160	160-220	220-440	440-1310	>1310
Selenium	7400	≤1000	1000-1200	1200-1400	1400-1800	1800-2500	2500-4900	4900-15000	>15000
PCBs	3.6	≤9	9-10	10-13	13-16	16-21	21-42	42-120	>120
DDTs	**21**	**≤220**	**220-260**	**260-310**	**310-390**	**390-520**	**520-1000**	**1000-2100**	**>2100**