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Pollutant bioaccumulation in the California spiny lobster (*Panulirus interruptus*) in San Diego Bay, California, and potential human health implications

Chad L. Loflen[a,*], Travis Buck[b], Autumn Bonnema[c], Wesley A. Heim[c]

[a] California Water Quality Control Board – San Diego Region, 2375 Northside Drive, Suite 100, San Diego, CA 92108, USA
[b] California Department of Fish and Wildlife, San Diego, CA 92123, USA
[c] Marine Pollution Studies Laboratory, Moss Landing Marine Laboratories, Moss Landing, CA 95039, USA

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ABSTRACT

While the California spiny lobster (*Panulirus interruptus*) is an important commercial and recreational fishery species in California, there is a lack of data on bioaccumulation for the species. This study examined pollutant tissue concentrations in lobsters from San Diego Bay, California. Observed lobster pollutant tissue concentrations in tail muscle were compared to State of California pollutant advisory levels. Concentrations were then used to conduct risk assessment using catch data from the California Department of Fish and Wildlife.

Study results found little bioaccumulation of organic pollutants in tail tissue, likely due to low observed lipids. Mercury was present, predominantly in methyl form, at concentrations above advisory levels. Recreational catch data for San Diego Bay showed increased non-cancer risk for fishers at the 90th percentile or greater of reported annual catch. Further studies should focus on non-tail tissues, as exploratory whole lobster samples ($n = 2$) showed elevated organic pollutants and metals.

1. Introduction

Pollutant bioaccumulation in marine organisms consumed by humans and aquatic dependent wildlife is a global concern due to increased health risks associated with consumption of contaminated food. In California, state and federal governmental bioaccumulation monitoring programs focus on popular sport and subsistence finfish species, with long-term monitoring in place for multiple species statewide (Davis et al., 2012). With the exception of marine biotoxins, the monitoring of bioaccumulation of toxicants in marine invertebrates in California, such as lobster, is not commensurate with finfish, despite their economic importance for commercial, recreational, and subsistence fisheries.

San Diego Bay is a highly urbanized and industrialized semi-enclosed bay located in the southwestern portion of California (Fig. 1). Despite draining multiple riverine watersheds that cumulatively encompass over 2300 km^2, San Diego Bay is predominantly saline due to limited freshwater inputs associated with a Mediterranean climate and upstream surface water impoundments (Largier et al., 1997). Over the past two hundred years the area surrounding the bay has been built out by development, including numerous shipyards, military installations, industrial production areas (e.g. aircraft), and high density residential and commercial buildings. Prior to the implementation of the U.S. Federal Clean Water Act, sewage and other waste from military, industrial, and residential areas was disposed of directly to the bay or its tributaries, without treatment (Terzich, 1965). Despite current state and federal environmental regulations eliminating waste discharges or requiring treatment, legacy pollutants remain in San Diego Bay sediments, including polychlorinated biphenyls (PCBs), organochlorine pesticides (pesticides), and metals (Fairey et al., 1998; SDRWQCB, 2012). These pollutants have been found to be bioavailable and bioaccumulate within various organismal trophic levels in San Diego Bay (Deheyn and Latz, 2006; Komoroske et al., 2011; Komoroske et al., 2012; Loflen, 2013; Bay et al., 2016). In 2013 the State of California's Office of Environmental Health Hazard Assessment (OEHHA) issued a consumption advisory for all of San Diego Bay, recommending anglers not consume or limit consumption of finfish in the bay, primarily due to cancer and non-cancer risks associated with PCBs and mercury (OEHHA, 2013).

The California spiny lobster (*Panulirus interruptus*) is an ecologically and economically important species that ranges from Magdalena Bay in Baja California Mexico to Point Conception in California (Tegner and Levin, 1983; Robles et al., 1990; Halpern et al., 2006; Loflen and Hovel, 2010). The species is subject to extensive fishing pressure from a

* Corresponding author.
E-mail address: chad.loflen@waterboards.ca.gov (C.L. Loflen).

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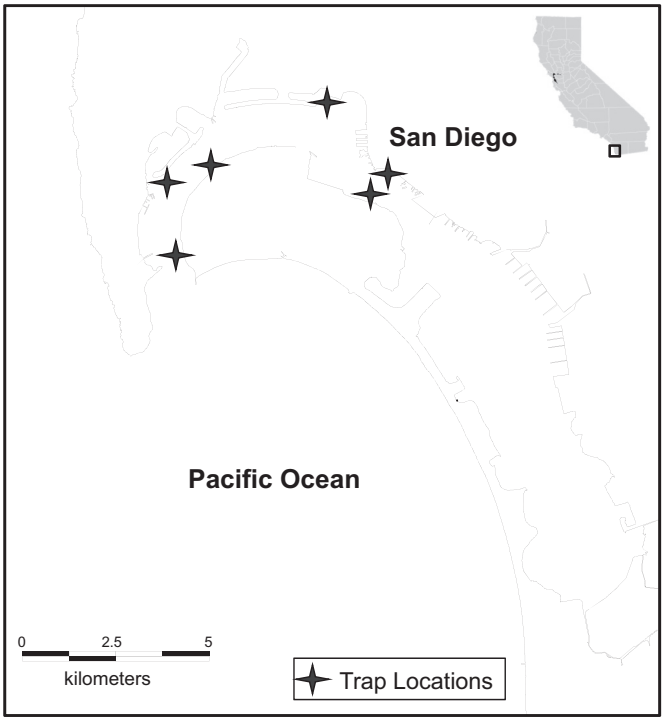

Fig. 1. Map of San Diego Bay, California, USA with marked lobster trap set locations.

commercial fishery, as well as recreational and subsistence fishers in California, with commercial landings worth an estimated $18.2 million for the 2014–2015 lobster fishing season, and an estimated worth of $33–40 million in consumer spending annually for the recreational fishery (CDFW, 2016). Recreational catch reporting requirements found the recreational catch to constitute 27–43% of overall landings (CDFW, 2016). While commercial take of lobsters in San Diego Bay is prohibited, for the 2015–2016 season San Diego Bay was found to produce the second largest recreational catch of lobsters of all the fishing locations statewide listed on the California Department of Fish and Wildlife's lobster report card (CDFW 2017 *pers. comm*).

Despite its importance as a Southern California fishery, a paucity of bioaccumulation information exists for California spiny lobsters, with most available data collected by the California Department of Public Health to test for marine biotoxin presence in internal organs, some of which can be targeted for consumption (e.g. hepatopancreas). Crustaceans, including lobsters, are capable of pollutant bioaccumulation, with prior studies showing bioaccumulation of specific pollutants occurring in Caribbean (*Panulirus gracilis*, Morales-Hernandez et al., 2004) and Australian (*Jasus edwardsii*, Fabris et al., 2006) Palinuridae "spiny" lobsters. In addition, the clawed American lobster (*Homarus americanus*, Hammerschmidt and Fitzgerald, 2006, Walker and Grant, 2015) and Norway lobster (*Nephrops norvegicus*, Canli and Furness, 1993) have been shown to bioaccumulate pollutants, with studies focusing on bioaccumulation of metals.

This study collected lobsters from the northern portion of San Diego Bay, California to: a) examine pollutant tissue concentrations related to the consumptive fishery; b) to obtain baseline data for on-going bay-wide cleanups; c) to assess the need for supplementing existing consumption advice for the bay by providing human health risk assessment based on CDFW reported local consumption rates for lobster (OEHHA, 2013); and d) to ascertain differences in bioaccumulation based on lobster size and sex. The northern portion of San Diego Bay was targeted for this study for the following reasons: it contains the highest level of fishing pressure (CDFW 2017 *pers. comm*), has well studied lobster movement (Hovel and Nielson, 2011), and has elevated levels of organic and metal pollutants in the tissues of finfish (Davis et al., 2007; Davis et al., 2012; Loflen, 2013; OEHHA, 2013).

2. Objectives

The purpose of this study was two-fold. First, to fill a data gap on the species, concentrations of pollutants in California spiny lobsters were analyzed to determine if bioaccumulation was occurring in northern San Diego Bay, which is likely representative of coastal embayments that contain persistent legacy organic and heavy metal pollutants within the species range in California. Second and most important, observed levels of contaminants in tail tissue were evaluated to determine if they present a potential human health risk to the public relative to potential and documented levels of consumption.

3. Materials and methods

3.1. Lobster collection and processing

Lobsters were collected via baited CDFW traps set overnight throughout northern San Diego Bay (Fig. 1) in April 2014 and August 2015. Prior lobster movement work within San Diego Bay has found lobsters to move throughout the northern portion without leaving the bay (Hovel and Nielson, 2011). A total of 36 lobsters were caught and selected for analysis during multiple-trap sets in 2014 and 2015. Following capture, each lobster was sexed, weighed, measured for carapace length, and examined for abnormalities (e.g., missing legs or antennae). Carapace length measurements of California spiny lobster are the legal metric used for minimum size determinations. Lobsters selected for tissue analysis were immersed and stored in wet ice, and delivered within 24 h for lab processing. Any lobsters not processed within 24 h were frozen until dissection and analysis.

3.2. Lobster dissection, compositing, and analysis

Lobster dissection and analysis was conducted by the State of California's Water Pollution Control Lab and Moss Landing Marine Laboratory, with QA/QC procedures followed as prescribed in the State of California's Surface Water Ambient Monitoring Program (SWAMP) Bioaccumulation Oversight Group Quality Assurance Program Plan (BOG QAPP, Bonnema, 2009) and in accordance with USEPA requirements and recommendations (USEPA, 2000). Lobsters were primarily dissected for tail muscle tissue only, as the fishery primarily targets the tail muscle tissue for consumption (CDFW, 2001). However, a small subset of lobsters (5 individuals, $n = 2$ composites) were dissected shell-off whole to evaluate if whole-organism pollutant levels could warrant additional future sampling.

With the exception of mercury (discussed further below), all but two lobsters were composited into groups for organics and metals analysis, with each composite containing three to four lobsters. Two lobsters were analyzed as "composites" containing one lobster in order to qualitatively evaluate variability between composite results containing multiple lobsters and individual lobster results. In total, 21 lobsters were used to create seven composites. Compositing multiple lobsters for metals and organics analysis was conducted to balance the cost for analysis with the objective of sampling a sufficient number of lobsters for the State of California to perform a consumption advisory update for San Diego Bay to include lobsters if warranted (OEHHA, 2013). Composites targeted lobsters above or near the minimum take size (82.5 mm carapace length), and were created using USEPA's 75% rule (USEPA, 2000), where the smallest lobster was no < 75% of the carapace length of the largest lobster in the composite. Lobster composites were analyzed for percent moisture and lipid content, PCBs, pesticides, polybrominated diphenyl ethers (PBDEs), and metals. Organochlorine pesticides were analyzed according to EPA 8081B, "Organochlorine Pesticides by Gas Chromatography" (USEPA, 1996a). PCBs and PBDEs were analyzed according to EPA 8082, "Polychlorinated Biphenyls