Marine Environmental Research 109 (2015) 69–80

Contents lists available at ScienceDirect

Marine Environmental Research

journal homepage: www.elsevier.com/locate/marenvrev

Movement patterns, habitat use and site fidelity of the white croaker (*Genyonemus lineatus*) in the Palos Verdes Superfund Site, Los Angeles, California

Barrett W. Wolfe*, Christopher G. Lowe

Dept. of Biological Sciences, California State University Long Beach, 1250 Bellflower Blvd., Long Beach, CA 90840, USA

A R T I C L E I N F O

Article history:
Received 4 January 2015
Received in revised form
3 June 2015
Accepted 5 June 2015
Available online 9 June 2015

Keywords:
VPS
Acoustic telemetry
Genyonemus lineatus
Organochlorine
DDT
Sciaenidae
Southern California
Model-bioaccumulation
Fish
Marine ecology
Indicator species
Habitat selection
Sediment pollution

A B S T R A C T

White croaker (*Genyonemus lineatus* family: Sciaenidae) are a schooling, benthic foraging fish historically associated with soft sediment and wastewater outfalls in southern California. While they are often used as an indicator species due to their high organochlorine contaminant loads, little is known of their movements in relation to contaminated habitats. A Vemco Positioning System acoustic telemetry array was used to collect fine-scale movement data and characterize the site fidelity, area use, and dispersal of 83 white croaker on the Palos Verdes Shelf Superfund Site, California over 27 months. White croaker generally demonstrated low residency and recurrence to the Palos Verdes Shelf, and were observed to be largely nomadic. However, individual behavior was highly variable. Although the entire monitored shelf was visited by tagged white croaker, habitats in 0–200 m proximity to wastewater outfalls and between 25 and 35 m depth were used most frequently. Approximately half of white croaker migrated into Los Angeles and Long Beach Harbors; areas where they may be targeted by subsistence fishers. A model framework for incorporating fish movement data into contaminant exposure estimates was developed to better understanding organochlorine contaminant exposure for planning future remediation and monitoring.

1. Introduction

Contaminants (e.g., organochlorines) in marine sediments threaten wildlife and human health throughout the world's oceans. Efforts to remediate and monitor affected environments increasingly involve modeling uptake and dispersion of contaminants through the ecosystem (Wickwire et al., 2011). However, these efforts are limited by a lack of information on interactions between contaminated sediments and the motile animals affected, and often hindered by a lack of basic movement data for species of concern. The Palos Verdes (PV) Shelf, California is one such contaminated site under management and impacted by data gaps. The Montrose Chemical Corporation of California, previously the world's largest manufacturer of the pesticide dichlorodiphenyltrichloroethane (DDT), released processed waste including DDT and its breakdown products DDE and DDD (herein referred to as 'DDTs') into the Los Angeles county sewer system from 1953 until the 1970s (USEPA, 2009). These DDTs were ultimately released through an effluent outfall pipe onto the PV Shelf (Stull et al., 1996; Young et al., 1976). A storm-water channel carried DDTs from the same source into the nearby Los Angeles Harbor. Polychlorinated bromides (PCBs), a family of compounds widely used at the time in industrial settings, were similarly deposited into both Los Angeles Harbor and PV Shelf sediments. In total, over 1000 tons of these organochlorine (OC) contaminants were released in sediments in the Los Angeles area. OCs have long half-lives, and while much of the historically contaminated sediments have been buried by newly deposited sediment, an estimated 20 tons of DDTs and 1 ton of PCBs remain in the bioavailable sediment layer on the PV shelf (ITSI-Gilbane, 2013). OCs are lipophilic, causing the compounds to bioaccumulate in the tissues of animals that filter contaminated marine sediments (Portmann, 1975). As they are passed through the food chain, OCs

* Corresponding author. 3438 Wela St. Honolulu, HI 96815, USA.
E-mail address: bwwolfe@hawaii.edu (B.W. Wolfe).

http://dx.doi.org/10.1016/j.marenvres.2015.06.002

biomagnify, increasing in concentration in higher trophic levels of the food chain. OCs are have been linked with a variety of physiological problems in both marine animals and humans, including elevated cancer risk, impaired reproduction, and endocrine disruption (Colborn et al., 1993; Cross and Hose, 1988; Hose et al., 1989; Longnecker et al., 1997; Myers et al., 1994; Tanabe, 2002). Subsistence fishers and high trophic level predators are particularly susceptible to the lipophilic OCs due to biomagnification through the food chain (Borgå et al., 2001; Hoekstra et al., 2003), and as a result there is currently a fish consumption advisory for many fish species in a large area encompassing the PV Shelf (Klasing et al., 2009).

Due to the impacts of OCs on marine resources in the Los Angeles area, in 1989 the US Environmental Protection Agency (USEPA) designated a portion of the PV shelf an operable unit of the Montrose Chemical Corporation Superfund Site. To mitigate the potential effects of sediment bound OCs, USEPA planned to place a 45 cm deep 'cap' of clean sediment over the most highly contaminated 1.3–2.74 km^2 area of the PV Shelf (USEPA, 2009). The capping plan was intended in part to prevent transfer of OCs from sediments into the food chain, and also includes fish tissue monitoring over time to determine how effective mitigation efforts have been. The degree to which a cap will prevent OC transfer into the food chain and ultimately to subsistence fishers is unpredictable without data on how fish are currently using the potential cap area as foraging habitat; the greater the degree to which it is used, the more effective the cap would prevent dietary OC transfer. An effectively designed fish tissue monitoring program would require similar information of where fish exposed OCs on the PV Shelf move and how frequently. Due to technical and logistical constraints of monitoring fish movements, currently these fine-scale, long-term fish movement data are absent from virtually all models of fish contamination. Previous attempts to collect fish movement data with regards to contamination were limited by resolution (Fabrizio et al., 2005) or spatial scale (Moser et al., 2013). However, new advances in acoustic telemetry allow for the collection of fine-scale movement data over large spatial scales for long periods of time. The Vemco VR2W Positioning System (VPS) utilizes a multi-lateration algorithm to position animals tagged with acoustic transmitters throughout an array of fixed acoustic receivers (Espinoza et al., 2011), and when applied to an indicator species the technology allows for the collection of animal movement data critical to informing management of contaminated areas.

Due to their propensity to aggregate and feed around contaminated wastewater outfalls (Ware, 1979), the white croaker (*Genyonemus lineatus* Family: Sciaenidae) has been widely used as an indicator species for monitoring biological contamination transfer in coastal California habitats, particularly southern California (Puffer and Gossett, 1983). As a demersal fish and important food fish and prey species (Love, 2011), they provide an excellent sentinel fish to monitor habitat use of the contaminated Palos Verdes Shelf. Previous modeling attempts to predict white croaker exposure and bioaccumulation rates have been hampered by the general lack of information about their movements. What is known of their ecology has been acquired from trawl and hook-and-line surveys, providing only an instantaneous snapshot of their distribution. Research conducted on the PV Shelf south to Huntington Flats suggests white croaker occur from the surf zone to 183 m depth, and are most commonly found in habitat 18–30 m deep. There is some evidence from trawl data suggesting white croaker may make diel (DeMartini and Allen, 1984) and seasonal (Allen and DeMartini, 1983) movements to deeper habitats. Another study found white croaker abundance was approximately ten times higher between the 18–27 m isobaths than the 59–73 m isobaths (Love et al., 1984). However, lacking actual movement data, previous studies have not determined what proportion, how often and for how long individual white croaker use particular depths, habitats, or areas of high sediment contamination. Further, current contaminant modeling efforts assume white croaker maintain a home range a fraction of the size of the PV Shelf (3 ± 4.7 km^2), based on movement studies of other benthic foragers like ocean whitefish (*Caulolatilus princeps*) and sheephead (*Semicossyphus pulcher*) (SWRCB, 2011). While there is currently little evidence for the assumption that the species maintains a relatively small home range, our understanding of how white croaker move contaminants through the region depends on this critical assumption. For example, contaminated white croaker have been sampled inside Los Angeles and Long Beach Harbors (NOAA, 2007) and it is currently unknown if these fish were exposed to contaminants within the harbors, or migrate far enough they can be exposed to PV Shelf sediments and then migrate to the harbors. Further, it is unknown how likely it is for white croaker exposed to contaminants on the PV Shelf to disperse into areas without fish consumption advisories, where they are currently considered safe to consume.

To better understand how white croaker are using contaminated areas of the PV Shelf and how habitat use may drive OC contaminant exposure and dispersal, this study used a VPS acoustic telemetry array to record the locations of tagged white croaker throughout an 8 km^2 area for a time spans of eight to 16 months. A larger passive acoustic telemetry array was used to determine degree of presence on the PV Shelf and in the nearby Los Angeles and Long Beach Harbors. As the PV Shelf is an ideal site to develop a widely applicable framework for monitoring fish movements, movement data are combined with available benthic habitat data and used to determine the use of contaminated areas of the PV Shelf. A modeling framework to estimate cumulative fish contaminant exposure was then developed. This study addresses four major goals: 1) determine the degree of site fidelity and residency of white croaker to the PV Shelf, 2) describe habitat use of white croaker on the PV Shelf including size of patches utilized, depth selection, and affinity for wastewater outfalls, 3) determine if white croaker tagged on the PV Shelf migrate into Los Angeles and Long Beach Harbors, areas where they are targeted by subsistence fishers, and 4) characterize patterns of exposure to sediment-bound OCs on the PV Shelf across white croaker.

2. Methods

2.1. Study site

The study was conducted on the southern end of Palos Verdes Shelf and outer San Pedro Bay (Fig. 1). The PV Shelf is located off of the Palos Verdes peninsula, Los Angeles County, California. The Shelf is bounded by Santa Monica Bay to the northwest and San Pedro Bay to the southeast. The focal point of the study was the most highly OC contaminated sediments, or 'Effluent Affected Sediment' (EAS) from between the 20 and 70 m isobaths (between rocky kelp forest and a sharp shelf break). This area is characterized by soft sediments with occasional reef outcroppings and four concrete outfall pipes that are oriented perpendicular to shore. The PV Shelf is relatively narrow, spanning 2–3 km from shore to shelf break. The outfall pipes are covered in rock ballast, forming structures varying from approximately 2–5 m in height and 8–10 m in width. Approximately 4 and 10 km east of the southeastern boundary of the PV Shelf study site are Angel's and Queen's gates. The gates serve as 700 m and 500 m wide entrances through the Federal Breakwater from outer San Pedro Bay into Los Angeles and Long Beach Harbors, respectively.