Science of the Total Environment 625 (2018) 344–354

Contents lists available at ScienceDirect

Science of the Total Environment

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

Applying acoustic telemetry to understand contaminant exposure and bioaccumulation patterns in mobile fishes

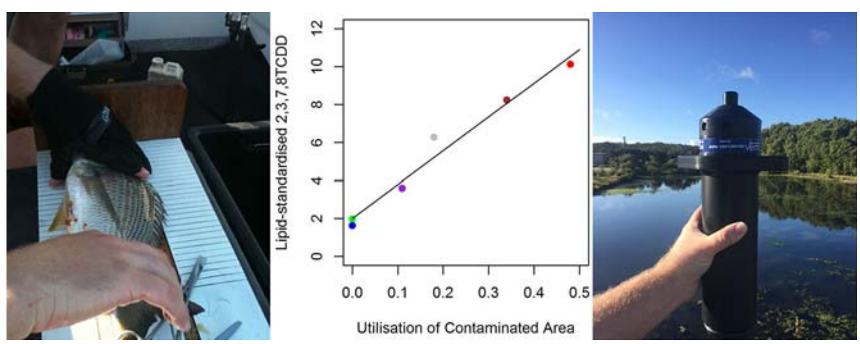
Matthew D. Taylor [a,b,*], Dylan E. van der Meulen [c], Stephanie Brodie [b], Gwenaël Cadiou [a,d], Nathan A. Knott [e]

[a] Port Stephens Fisheries Institute, New South Wales Department of Primary Industries, Taylors Beach Rd, Taylors Beach, New South Wales 2316, Australia
[b] School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, New South Wales 2051, Australia
[c] Batemans Bay Fisheries Centre, NSW Department of Primary Industries, PO Box 17, Batemans Bay, New South Wales 2536, Australia
[d] Sydney Institute of Marine Science, Mosman, New South Wales 2088, Australia
[e] New South Wales Department of Primary Industries, Huskisson, New South Wales 2540, Australia

HIGHLIGHTS

- Fish movements can be studied using acoustic telemetry.
- Patterns in fish movement may help explain patterns in biota contamination.
- Fish presence in contaminated areas explained 84–98% of variation in biota [PCDD/F].
- Acoustic telemetry represents a powerful complementary tool in ecotoxicology.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 20 September 2017
Received in revised form 27 November 2017
Accepted 16 December 2017
Available online xxxx

Editor: Daniel Wunderlin

Keywords:
Persistent organic pollutants
Ecotoxicology
Toxicology
Dioxin
Bioaccumulation
Spatial contamination patterns
Ecological exposure

ABSTRACT

Contamination in urbanised estuaries presents a risk to human health, and to the viability of populations of exploited species. Assessing animal movements in relation to contaminated areas may help to explain patterns in bioaccumulation, and assist in the effective management of health risks associated with consumption of exploited species. Using polychlorinated dibenzodioxin and polychlorinated dibenzofuran (PCDD/Fs) contamination in Sydney Harbour estuary as a case study, we present a study that links movement patterns resolved using acoustic telemetry to the accumulation of contaminants in mobile fish on a multi-species basis. Fifty-four individuals across six exploited species (Sea Mullet *Mugil cephalus*; Luderick *Girella tricuspidata*; Yellowfin Bream *Acanthopagrus australis*; Silver Trevally *Pseudocaranx georgianus*; Mulloway *Argyrosomus japonicus*; Yellowtail Kingfish *Seriola lalandi*) were tagged with acoustic transmitters, and their movements tracked for up to 3 years. There was substantial inter-specific variation in fish distribution along the estuary. The proportion of distribution that overlapped with contaminated areas explained 84–98% of the inter-specific variation in lipid-standardised biota PCDD/F concentration. There was some seasonal variation in distribution along the estuary, but movement patterns indicated that Sea Mullet, Yellowfin Bream, Silver Trevally, and Mulloway were likely to be exposed to contaminated areas during the period of gonadal maturation. Acoustic telemetry allows examination of spatial and temporal patterns in exposure to contamination. When used alongside biota sampling and testing, this offers a powerful approach to assess exposure, bioaccumulation, and potential risks faced by different species, as well as human health risks associated with their consumption.

* Corresponding author at: Port Stephens Fisheries Institute, New South Wales Department of Primary Industries, Taylors Beach Rd, Taylors Beach, New South Wales 2316, Australia.
E-mail address: matt.taylor@dpi.nsw.gov.au (M.D. Taylor).

https://doi.org/10.1016/j.scitotenv.2017.12.177

1. Introduction

Estuaries support maritime activities (such as shipping and fishing) essential to economic development (Johnston et al., 2015), and consequently cities often develop around estuarine ecosystems (Lindegarth and Hoskin, 2001). While commercial fisheries in and around urbanised estuaries are important to feed large urban populations, recreational fisheries also harvest these resources for both sport and personal consumption (Schramm and Edwards, 1994). In fact, the artificial structures that arise alongside development in estuaries can act to either enhance populations of exploited species (McKinley et al., 2011), or increase their vulnerability to harvest (Lowry et al., 2017). Therefore, urbanised estuaries support productive and valuable fisheries that are important for both sustenance and the recreational pursuits of urban communities (Schramm and Edwards, 1994). However, there are many and varied sources of contamination in urbanised estuaries, and the presence of contaminants in the food chain may present a risk to these fisheries and the communities that rely on them (Burger, 2004; Burger et al., 1993).

The presence of contaminants in exploited species has been studied in detail, and consequently there are many published examples of contamination in seafood (see Shahidul Islam and Tanaka, 2004). The accumulation of such contaminants in the tissues of aquatic species depends on a myriad of factors including their physiology, ecology, behaviour, and the chemical properties of the contaminant itself. Ultimately, the ecology of aquatic organisms can either moderate or exacerbate their exposure to contaminants, and this in turn affects human health risks associated with their consumption. For example, bioaccumulation of contaminants in mobile or migratory species may spread human health risk to other areas away from the contaminant source (e.g. do Amaral Kehrig and Maim, 1999). Conversely, for contaminants that can be depurated by organisms, movement away from a contaminated area may reduce contaminant concentrations in biota (e.g. Taylor et al., 2017b) and make spatial management arrangements (for example provision of dietary advice covering certain areas) more effective. Animal movements are rarely incorporated in toxicological or ecotoxicological studies in a quantitative fashion. Assessing animal movements in relation to contaminated areas may help to explain spatial patterns in animal exposure and bioaccumulation, as well contribute to the management of human-health risks associated with exploited species.

Acoustic telemetry allows the monitoring of fish movement and migration over a spectrum of spatial and temporal scales, and is a broadly useful tool in both fisheries and conservation management (Taylor et al., 2017a). Acoustic telemetry generally involves the implantation of a transmitter into an aquatic organism, and subsequent tracking of movements through a network of fixed-position receivers (Payne et al., 2015) or real-time monitoring using a boat-based hydrophone (Pursche et al., 2013), and can yield high resolution positional data. While acoustic telemetry has been proposed as a means to study fish behavioural responses to contamination (Hellström et al., 2016), it has rarely been applied to investigate bioaccumulation processes (or exposure patterns) in aquatic organisms. The few examples that are available, however, show that this can provide for powerful conclusions surrounding the interaction between point sources of contamination and exploited species (e.g. Wolfe and Lowe, 2015).

Polychlorinated dibenzodioxins and polychlorinated dibenzofurans (PCDD/Fs) are persistent organochlorine contaminants that bioaccumulate in aquatic food webs (Opperhuizen and Sijm, 1990), and pose a risk to human health through consumption of contaminated seafood (Manning et al., 2017). Furthermore, PCDD/Fs (particularly 2,3,7,8-tetrachloro-dibenzo dioxin TCDD, the most toxic dioxin compound) can lead to reproductive toxicity in fish (King-Heiden et al., 2012), which may contribute to population-level effects for species that are exposed to these compounds during the period of gonadal maturation. Consequently, it is important to understand exposure to PCDD/F in both a fisheries and biological context, especially in urbanised estuaries.

Numerous urbanised estuaries throughout the world are contaminated with these compounds, however some of the highest estuarine sediment concentrations yet to be detected occur in Sydney Harbour estuary, New South Wales, Australia (Birch et al., 2007). This has led to the accumulation of PCDD/F in the edible tissues of a range of exploited species (Manning et al., 2017, as outlined below). In broad terms, we sought to highlight the utility of acoustic telemetry in contamination research, through a case study evaluating movement patterns of exploited fish species in Sydney Harbour estuary in the context of this existing PCDD/F contamination data. Specifically, this study addressed three objectives: 1) initial characterisation of fish movement patterns along the length of the estuary; 2) interpretation of patterns in bioaccumulation at the species level, given differences in movement patterns; and 3) evaluation of potential exposure patterns during the period of gonadal maturation of exploited species.

2. Materials and methods

2.1. Study area, contamination, and management

Sydney Harbour has a long history of contamination from industrial sources (Birch et al., 2008). PCDD/Fs contamination originated in Homebush Bay (Fig. 1), with elevated concentrations in the estuary arising from the manufacture of pesticides and herbicides, and the reclamation of land using contaminated fill (Birch et al., 2007). The PCDD/F compounds within the estuarine sediments are generally dominated by TCDD (Fig. 2). While the estuary supported a productive fishery for over 200 years, data derived from a comprehensive PCDD/F sampling program in sediment and biota led to the temporary, then permanent closure of commercial fisheries in the estuary (Langdon et al., 2017). While the estuary remained open to recreational fishing, advisories were issued to anglers by government to avoid consuming fish caught in the western zone (Fig. 1), and dietary advice outlining precautionary consumption limits were issued for fish caught in the eastern zone (see http://www.foodauthority.nsw.gov.au/foodsafetyandyou/special-care-foods/sydney-harbour-seafood; accessed 25 May 2017). The Sydney Harbour Bridge was selected as the main management boundary between these zones due to its prominence as a recognisable landmark, and because it roughly reflected coarse spatial trends in contaminant loads in the edible tissues of key recreationally targeted fishes (Manning et al., 2017). There is, however, no physical barrier preventing movement of fish between the two areas.

2.2. Acoustic array

The Sydney Harbour acoustic array was established by New South Wales Department of Primary Industries in 2008, and forms a key component of the national Integrated Marine Observing System Animal Tracking Facility (Taylor et al., 2017a). The array consists of 51 fixed-position Vemco VR2W receivers, which are configured as a series of single or multiple receiver gates distributed from the mouth of the estuary to Parramatta (~30 km upstream, where a man-made weir delimits the main extent of the estuary). Multi-receiver gates are deployed where the width of the estuary exceeds the range of the receiver from its point of mooring, and the gates are regularly spaced along the estuary (Fig. 1). Importantly, the array also covered the area with the highest contamination levels (see Fig. 2), near Homebush Bay (see Fig. 1), in the upper region of the estuary. Due to the weir and relative lack of regular freshwater inflow, the estuary itself is highly marine dominated, with only moderately brackish regions in the upper reaches. Consequently, variation in salinity along the length of the array is reasonably low.

Receivers were deployed in an inverted configuration attached to existing navigational markers (wherever possible), and were continually active. When an acoustic tag transmitted a coded signal within the range of a receiver, the time, date, and tag identity code were logged