Science of the Total Environment 610–611 (2018) 402–411

Contents lists available at ScienceDirect

Science of the Total Environment

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

Persistent organic pollutants in fat of three species of Pacific pelagic longline caught sea turtles: Accumulation in relation to ingested plastic marine debris

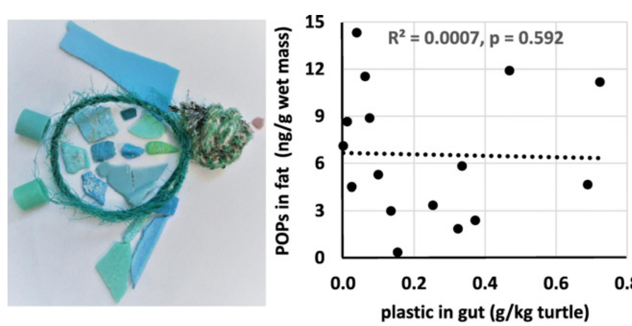
Katharine E. Clukey [a], Christopher A. Lepczyk [a,b], George H. Balazs [c], Thierry M. Work [d], Qing X. Li [e], Melannie J. Bachman [f], Jennifer M. Lynch [g,*,1]

[a] Department of Natural Resources and Environmental Management, University of Hawai'i at Mānoa, Honolulu, HI 96822, United States
[b] Auburn University, School of Forestry and Wildlife Science, Auburn, AL, United States
[c] Pacific Islands Fisheries Science Center, National Marine Fisheries Service, Honolulu, HI, United States
[d] U.S. Geological Survey, National Wildlife Health Center, Honolulu Field Station, Honolulu, HI, United States
[e] Department of Molecular Biosciences and Bioengineering, University of Hawai'i at Mānoa, Honolulu, HI 96822, United States
[f] Chemical Sciences Division, National Institute of Standards and Technology, Charleston, SC, United States
[g] Chemical Sciences Division, National Institute of Standards and Technology, Kaneohe, HI, United States

HIGHLIGHTS

- Persistent organic pollutants have rarely been measured in pelagic or Pacific sea turtles.
- Ingesting marine debris may expose sea turtles to persistent organic pollutants.
- We assessed correlations between ingested plastics and fat [POP] in two species.
- GC/MS & LC/MS/MS were used to measure POPs, including brominated flame retardants.
- Results suggest that ingested plastics are a minor source of POP exposure.

GRAPHICAL ABSTRACT



Plastic ingestion not correlated to POPs in sea turtles.

ARTICLE INFO

Article history:
Received 27 May 2017
Received in revised form 27 July 2017
Accepted 27 July 2017
Available online xxxx

Editor: D. Barcelo

Keywords:
POPs
PCBs
DDT
Pelagic Pacific

ABSTRACT

In addition to eating contaminated prey, sea turtles may be exposed to persistent organic pollutants (POPs) from ingesting plastic debris that has absorbed these chemicals. Given the limited knowledge about POPs in pelagic sea turtles and how plastic ingestion influences POP exposure, our objectives were to: 1) provide baseline contaminant levels of three species of pelagic Pacific sea turtles; and 2) assess trends of contaminant levels in relation to species, sex, length, body condition and capture location. In addition, we hypothesized that if ingesting plastic is a significant source of POP exposure, then the amount of ingested plastic may be correlated to POP concentrations accumulated in fat. To address our objectives we compared POP concentrations in fat samples to previously described amounts of ingested plastic from the same turtles. Fat samples from 25 Pacific pelagic sea turtles [2 loggerhead (*Caretta caretta*), 6 green (*Chelonia mydas*) and 17 olive ridley (*Lepidochelys olivacea*) turtles] were analyzed for 81 polychlorinated biphenyls (PCBs), 20 organochlorine pesticides, and 35 brominated flame-retardants. The olive ridley and loggerhead turtles had higher ΣDDTs (dichlorodiphenyltrichloroethane and metabolites) than ΣPCBs, at a ratio similar to biota measured in the South China Sea and southern California. Green turtles had a ratio close to 1:1. These pelagic turtles had lower POP levels than previously reported in nearshore

* Corresponding author at: NIST at Hawaii Pacific University, 45-045 Kamehameha Hwy, Kaneohe, HI 96744, United States.
E-mail address: Jennifer.lynch@nist.gov (J.M. Lynch).

[1] Previously Jennifer M. Keller.

http://dx.doi.org/10.1016/j.scitotenv.2017.07.242
0048-9697/Published by Elsevier B.V.

Marine turtles
Plastic pollution

turtles. POP concentrations were unrelated to the amounts of ingested plastic in olive ridleys, suggesting that their exposure to POPs is mainly through prey. In green turtles, concentrations of ΣPCBs were positively correlated with the number of plastic pieces ingested, but these findings were confounded by covariance with body condition index (BCI). Green turtles with a higher BCI had eaten more plastic and also had higher POPs. Taken together, our findings suggest that sea turtles accumulate most POPs through their prey rather than marine debris.

1. Introduction

Persistent organic pollutants (POPs) are man-made chemicals that are extremely persistent, globally transported by atmospheric and oceanic currents, and toxic (Jones and de Voogt, 1999; Wania and Mackay, 1995). POPs include a variety of compounds most of which are lipophilic and biomagnify in food webs, including polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and organochlorine pesticides (OCPs) such as dichlorodiphenyltrichloroethane and its main metabolites (DDTs). The uses of POPs are highly varied, but include pesticides, flame retardants, and other household and industrial purposes (United Nations Environmental Programme, 2017). In many instances POPs are found in environments far from their original source, with transport occurring via the food web, agricultural runoff, atmospheric circulation (Jones and de Voogt, 1999), and ocean circulation (Wania and Mackay, 1995).

POPs have contributed to population declines of several wildlife species, including alligators and birds (Carson, 1962; Fox, 2001; Guillette et al., 1994). In the case of sea turtles, effects of environmental pollutants are still poorly understood (Keller, 2013). The International Union on the Conservation of Nature (IUCN) lists the sea turtle species found in this study as endangered (green [*Chelonia mydas*] globally), vulnerable (olive ridley [*Lepidochelys olivacea*], loggerhead [*Caretta caretta*] turtles), or least concern (green turtles of the Hawaiian subpopulation) (IUCN, 2017). Sea turtles have faced a long list of human impacts affecting their survival, especially direct take and fisheries bycatch, but also anthropogenic chemical contamination (Lutcavage et al., 1997). Although POP concentrations in sea turtles are low relative to other wildlife that feed at higher trophic levels, concentrations have been significantly correlated with several health indicators, including white blood cell counts and some plasma chemistry measurements (Keller et al., 2004b, 2006).

The East Coast of the United States has been the region most extensively studied for POPs in sea turtles (Keller, 2013). While there are data on POP concentrations in sea turtle species inhabiting the Pacific Ocean, knowledge of POP concentrations in sea turtles surrounding the Hawaiian Islands are limited, with only three published studies (Aguirre et al., 1994; Keller et al., 2014a; Miao et al., 2001). Notably, only two of these three studies used methods sensitive enough to detect POPs. Recently, baseline data on POPs have been published for sea turtles in coastal areas of Australia, Japan, Baja California, and Malaysia (Hermanussen et al., 2008; Labrada-Martagon et al., 2011; Richardson et al., 2010; van de Merwe et al., 2010), but data are still lacking in pelagic areas. Additionally, most of these Pacific studies focused on green turtles with only five olive ridleys and five loggerheads having been measured for POPs (Gardner et al., 2003; Richardson et al., 2010). Hence, an assessment of POP exposure in vast regions inhabited by sea turtle species of all size classes is important for better understanding this threat to different life stages and populations of these protected species.

POP exposure occurs mostly through the food web, and broad comparisons across all studies support the general conclusion that POP concentrations follow trophic status and are highest in Kemp's ridley sea turtles (*Lepidochelys kempii*), followed by loggerhead, leatherback (*Dermochelys coriacea*) and finally green turtles (Keller, 2013). Data on olive ridleys have been too limited to rank this species among other sea turtles by POP concentrations. In an 18-year study of diet content analysis of sea turtles captured in American Samoan and Hawaiian pelagic longline fisheries, olive ridleys were found to be opportunistic generalists consuming gelatinous zooplankton and fish, anthropogenic debris (Wedemeyer-Strombel et al., 2015), and often would graze from longline hooks (Work and Balazs, 2002). Juvenile pelagic green turtles captured as bycatch in Pacific longlines were found to be opportunistic, mainly carnivorous, feeding at or near the surface (Parker et al., 2011). Pacific loggerheads fed primarily at the surface on molluscs, hydrozoans and pyrosomes with few deep water prey (Parker et al., 2005). These feeding habits suggest that olive ridleys would likely rank somewhere between Kemp's ridleys and loggerheads for POP concentrations based on their trophic status. Green turtles often rank lowest in POP concentrations (Keller, 2013), but the ranking of green turtles in this study are more difficult to predict. While they are pelagic (farther from contaminant sources) and younger (fewer years to accumulate contaminants), they feed at a higher trophic level than the older neritic herbivorous phase previously analyzed.

One potential route of exposure of sea turtles to POPs is through ingestion of plastic debris (Teuten et al., 2009). The hydrophobic nature of plastic attracts chemicals, such as POPs, to its surface, and POPs have been found in plastic debris collected from beaches around the world (Endo et al., 2005; Mato et al., 2001; Ogata et al., 2009; Rios et al., 2007), including Hawaii (Heskett et al., 2012). In a companion study to this paper, 92% of the turtles used in this study were found to have ingested plastic debris (Clukey et al., 2017). Furthermore, correlations of chemicals found in seabird fat and their ingested plastics suggest that plastic may be an additional source of exposure to these classes of POPs (Ryan et al., 1988; Tanaka et al., 2013; Yamashita et al., 2011). Specifically, higher brominated PBDE congeners have been found in seabird tissues, which were not present in their prey, but that are incorporated in plastics and textiles as flame-retardants (Tanaka et al., 2013).

Given our limited knowledge about contaminants in the Pacific pelagic zone, we sought to provide baseline contaminant levels of three species of pelagic Pacific sea turtles and spatial trends of contaminant levels in sea turtles inhabiting the Pacific Ocean. In addition, because POPs can accumulate with age or be offloaded from females into eggs (Stewart et al., 2011), we examined POP concentrations between sexes and across lengths and body condition indices of turtles. Additionally, we hypothesized that if ingesting plastics is a significant source of POP exposure, then the amount of ingested plastic would be correlated with the concentrations of POPs accumulated in fat, as seen previously in seabirds (Ryan et al., 1988; Yamashita et al., 2011).

2. Methods

2.1. Sample collection

The U.S. National Oceanic and Atmospheric Administration (NOAA) Pacific Islands Regional Office (PIRO) uses observers on the Hawaiian and American Samoan longline fisheries to collect fisheries catch and bycatch data. Between June 2012 and December 2013, latitude 13.5 °S and 29.6 °N, and longitude 140 °W and 170 °W (Fig. 1), 25 sea turtles (two loggerhead, six green, and seventeen olive ridley turtles) drowned as bycatch in these fisheries were sampled. Observers recorded the capture latitude and longitude and sent the frozen carcasses to NOAA, National Marine Fisheries Service, Pacific Islands Fisheries Science Center