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Bioaccumulation of mercury and other metal contaminants in invasive lionfish (*Pterois volitans/miles*) from Curaçao

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ABSTRACT

A wide range of ecological and environmental factors influence metal bioaccumulation in fish. Studies of mercury and other metal contaminants in invasive Indo-Pacific lionfish are limited, yet consumption of the invasive predator is increasingly utilized as a management strategy. In this study, we examined the effects of body size, body condition, sex, trophic level, carbon source, diet, depth and capture location on mercury concentrations in lionfish collected from Curaçao. In addition, we examined whether or not a local petroleum refinery is the source of metal contamination in lionfish. Mercury concentrations ranged from 0.008 to 0.106 mg/kg and we found no effect of the petroleum refinery on metal bioaccumulation in lionfish. Low concentrations of metal contaminants indicate lionfish from Curaçao are safe for human consumption.

1. Introduction

Mercury (Hg) is a chemical contaminant deposited by natural and anthropogenic sources. In aquatic systems, Hg is converted to the toxic methylmercury, which bioaccumulates and biomagnifies up food chains to concentrations harmful to human health when higher trophic level organisms are consumed. Hg bioaccumulation in fish is influenced by a variety of ecological factors such as body size, age, and trophic position. For example, negative relationships exist between Hg and both fish body condition (mass × length^{-3}) (Ackerman and Eagles-Smith, 2010; Baumann et al., 2017; Greenfield et al., 2001) and benthic food sources ($\delta^{13}C$) (Chen et al., 2014; Power et al., 2002; Stewart et al., 2008), whereas Hg is often found in higher concentrations in larger bodied fish (Kim, 1995; Power et al., 2002; Trudel and Rasmussen, 2006) existing deeper in the water column (Choy et al., 2009) and at higher trophic levels ($\delta^{15}N$) (Bank et al., 2007; Cabana and Rasmussen, 1994; Kidd et al., 1995; Power et al., 2002).

The Indo-Pacific lionfish (*Pterois volitans* and *P. miles*) is a predatory fish invasive to the Western Atlantic Ocean, Gulf of Mexico, and Caribbean Sea (Schofield, 2010, 2009). As a mesopredator, lionfish have the potential to bioaccumulate high concentrations of Hg and other pollutants. Humans have responded to the expanding range of invasive lionfish through targeted removals using spearfishing and culling tournaments to encourage management through consumption (Ali et al., 2013; Barbour et al., 2011; de León et al., 2013; Frazer et al., 2012; Morris, Jr. et al., 2011). Although lionfish are not a staple food source for the local population, select restaurants around Curaçao and other Caribbean islands support spearfishing efforts by offering lionfish on their menu (Ritger, *personal observation*). Previous studies of contaminant loads in lionfish from Jamaica (Hoo Fung et al., 2013) and Florida (Huge et al., 2014; Tremain and O'Donnell, 2014) have found relatively low concentrations of Hg in lionfish, although there is variability between regions.

In addition to an emerging lionfish fishery, Curaçao houses a petroleum refinery, Refinería Isla, which has been the source of numerous oil pollution incidents (Govers et al., 2014; Nagelkerken and Debrot, 1995) and local health issues suspected to be linked to chronic exposure to refinery emissions (Pulster, 2015; Sanhueza et al., 1982; van der Torn, 1999). Additionally, seagrasses around Curaçao have high concentrations of chromium (Cr) and other metal contaminants associated with coastal pollution (Govers et al., 2014). Elevated levels of cadmium (Cd), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), vanadium (V), and zinc (Zn) are also often measured in aquatic systems proximate to petroleum refineries (Akpoveta and Osakwe, 2014; Freije, 2015; Guzmán and Jarvis, 1996; Onwumere and Oladimeji, 1990; Traven et al., 2013; Wake, 2005). Despite these known pollutant sources and consequences, contaminant loads in locally consumed fishes in Curaçao have not been examined.

The increased consumption of invasive lionfish as a management solution across the invaded region necessitates further study in order to

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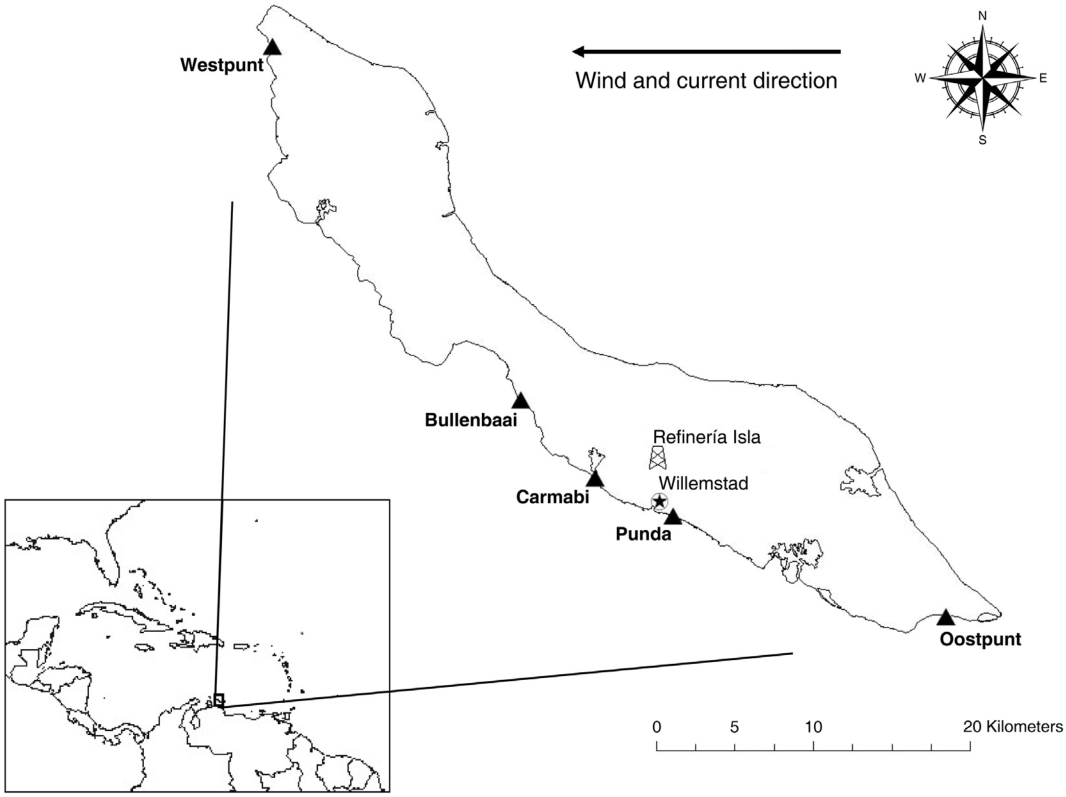

Fig. 1. Map of sampling sites around Curaçao where lionfish were collected for this study.

assess potential human exposure to pollutants when lionfish are consumed. In this study, we investigated metal contaminants in lionfish across a range of sites around Curaçao, addressing the following questions: (1) Do ecological factors (e.g. body size, body condition, sex, trophic level, carbon source, diet, depth, and capture location) predict Hg concentrations in Curaçaoan lionfish? (2) Is Refinería Isla a source of metal contamination in Curaçaoan lionfish? (3) Do metal concentrations in Curaçaoan lionfish pose a human exposure risk? We predicted higher Hg concentrations in lionfish with larger body sizes and poorer body conditions, and that Hg concentrations would be related to both pelagic diet (decreasing $\delta^{13}C$) and trophic level (increasing $\delta^{15}N$). We also predicted metal contaminants linked to petroleum refining would be higher in lionfish captured closer to Refinería Isla, posing a potential human exposure risk.

2. Materials and methods

2.1. Study area

Curaçao is a developed island located in the southern Caribbean Sea (Fig. 1). It is surrounded by fringing reefs that slope downward from a depth of approximately 7–12 m (Bak, 1975). Lionfish have been observed in shallow rocky habitats and small patch reefs above 5 m, in addition to depths past recreational diving limits on the fringing reefs (Ritger, *personal observation*).

Lionfish were collected from five sampling sites along the leeward coast of Curaçao from September 2015 to June 2016. Sampling sites were selected in relation to Refinería Isla (Fig. 1). As a result of reduced lionfish abundances due to heavy spearfishing pressure along the northwestern coast, two proximate sampling sites < 5 km apart were combined to denote a single site, "Westpunt". All other sampling sites were separated by at least 5 km.

Westpunt, Bullenbaai, and Carmabi are located west of the refinery, and Punda and Oostpunt are located east of the refinery. Westpunt has little coastal development but experiences high fishing pressure and, as a result, reef fish biomass is very low (Vermeij, 2017). Low fishing pressure contributes to higher reef fish biomass at Bullenbaai, Carmabi, Punda, and Oostpunt, though coastal development ranges from heavily developed at Punda, the closest sampling site to Willemstad (Curaçao's capital and largest city), to undeveloped coastline at Oostpunt, which has some of the healthiest reefs on the island (Vermeij, 2017). Carmabi is subject to boating activity, deforestation, construction, and sewage pollution (Govers et al., 2014; Vermeij, 2017), while Bullenbaai has historically been exposed to chronic oil spills due to its close proximity to oil terminals (Nagelkerken and Debrot, 1995).

2.2. Sample collection

Lionfish were collected on SCUBA using stainless steel pole spears. In order to ensure successful recovery of stomach contents, lionfish were collected between 6:00 and 6:30, and 17:30 and 19:00, the time periods when lionfish exhibit the highest foraging activity levels (Green et al., 2011). Due to logistical constraints, lionfish were collected from Oostpunt between approximately 8:30 and 12:00, but stomach contents were not recovered for these fish. When a fish was collected, depth of capture was noted. After capture, fish were immediately returned to the laboratory at the Caribbean Marine Biological Institute (CARMABI), where each individual's sex, weight (wet weight to the nearest g), total length and standard length (to the nearest mm) were recorded. Mouth and gills were examined for regurgitated prey, and whole stomachs were removed for immediate stomach content analysis. Stomach content analysis was performed using a dissecting microscope and prey items were visually identified to the lowest taxonomic level possible. When immediate identification was not possible, photographs of identifying features such as scales and otoliths were taken for identification at a later date. White muscle tissue anterior to the first dorsal fin and above the lateral line was collected from each lionfish, avoiding the region where the lionfish was speared. All tissue samples were collected