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The invasive lionfish, *Pterois volitans*, used as a sentinel species to assess the organochlorine pollution by chlordecone in Guadeloupe (Lesser Antilles)

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ABSTRACT

In Guadeloupe, many marine organisms are affected by an organochlorine pollution used in the past by the banana industry to fight against the banana weevil. In the present study, we evaluated the level of contamination of the invasive Indo-Pacific lionfish, *Pterois volitans*, all around the island. Concentrations of chlordecone varied from 3 to 144 $\mu g.kg^{-1}$ wet weight. The highest concentrations were recorded when samples were captured in the marine zones located downstream of the previous banana plantations. This contamination seemed to decrease rapidly with the distance from the coast. Mean concentration of chlordecone in *Pterois volitans* was higher than that of five other fish species collected in similar sites. Due to its position at the top of the trophic web, lionfish was affected by bioaccumulation of chlordecone and can be used as a sentinel species to assess and control the level of contamination of the marine environment by chlordecone.

1. Introduction

Guadeloupe is an overseas French territory located in the Lesser Antilles. On the island, the production of bananas represents one of the principal economical activities, with approximately 60,000 t of commercial production of bananas in 2010. Banana plants grow in the southern Guadeloupe, which is characterized by the presence of a volcano and, as a consequence, by intense rainfall events. To maintain a good yield and fight against the banana weevil, an organochlorine pesticide called "chlordecone" was used in Lesser Antilles from 1972 to 1993. This chemical, commercialized as "Kepone", was first manufactured in Virginia in 1958. The manufacturing of Kepone was stopped in 1975, when workers from the site of production began to show severe and diverse pathologies associated to their exposure. The local environment and wildlife was also impacted because of the sewage system of the factory (Epstein, 1978; Huff and Gerstner, 1978).

In contrast, in the French West Indies, the use of this chemical continued until 1993. Approximately 6200 ha are moderately to heavily polluted by chlordecone (Cabidoche and Lesueur Jannoyer, 2011), which represents about 25% of the land surface used for agriculture in Guadeloupe. The risk of contamination of soils is the highest in the south of Basse-Terre (one of the two islands of Guadeloupe), where previous banana plantations were located. Chlordecone is a very persistent molecule in the environment with a half-life estimated to 600 years (Cabidoche et al., 2009). Organochlorine molecules are hydrophobic and adsorbed onto organic matter of the soil. With the erosion of soil particles, desorption phenomena, slow solubilization and infiltration processes, these compounds reach runoff and ground waters that end up directly into the sea (Cattan et al., 2006; Coat et al., 2006; Cabidoche et al., 2009).

Since 2003, several sampling surveys have been conducted in Guadeloupe to evaluate the level of contamination by chlordecone of fishes, crustaceans and mollusks (Bouchon and Lemoine, 2003, 2007; Bertrand et al., 2013). In 2008, the French food and safety authorities lowered the maximal residue limit (MRL) authorized for human consumption and commercialization of sea products from 200 to 20 $\mu g.kg^{-1}$ of wet weight and regulated the fishing activities around the island. The most contaminated marine areas, located downstream of the banana plantations, are now totally closed to fishing activities. The boundary areas are classified as areas of fishing restrictions in which it is not possible to fish a list of targeted species. These rules have been established to protect the health of the local population, especially because seafood represents a large part of the Caribbean gastronomy.

In 2009, the occurrence of a new fish species, the invasive lionfish *Pterois volitans*, was recorded in Guadeloupe. This species, native of Indo-Pacific Ocean, first appeared in Florida in 1992 and then colonized most of the coasts of the Gulf of Mexico and the Caribbean Sea. The population of lionfish rapidly increased between 2004 and 2010, and their density reached around 400 individuals per hectares in Florida, i.e. five times higher than in their native environment (Fishelson, 1997; Green and Côté, 2009). This predator is now very abundant around Guadeloupe and represents a high threat for the local biodiversity (Albins

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and Hixon, 2008; Green et al., 2012; Côté et al., 2013). Several initiatives have been proposed to control and manage the lionfish invasion in the Caribbean (Morris and Whitfield, 2009; Akins, 2012). Human consumption of lionfish is a plausible option for creating harvest pressure, as lionfish meat has good organoleptic qualities. However, before supporting the fishing and the commercialization of lionfish in Guadeloupe, a study was necessary to evaluate the risks of its consumption linked with its potential contamination by chlordecone.

Following this study, we suggest that lionfish, which are particularly abundant and sedentary, could be used as sentinel species to evaluate the level of contamination by pesticides around the island and to begin long-term monitoring of the contamination. The concept of "sentinel species" is important in the environmental health sciences because sentinel species can provide integrated and relevant information on the types, the amounts and the bioavailability fraction of pollutant in an ecosystem by retaining the pollutant in their tissues (Beeby, 2001; Basu et al., 2007). Fish are often used as sentinel species to assess the level of contamination of a region by organochlorine pollutants or metals (Albalat et al., 2002; Gibbons et al., 2009; Cresson et al., 2014). But few studies have exploited the abundance of invasive marine species to use them as sentinel species (Linde-Arias et al., 2008). Invasive species, like lionfish, could represent excellent models due to their abundance, their widespread distribution, their sedentary behavior and their high trophic level (Beeby, 2001; Basu et al., 2007).

In the present study, we studied chlordecone contamination of the invasive Indo-Pacific lionfish *Pterois volitans* in Guadeloupe. The objectives of this study were: 1) to evaluate the level of contamination of lionfish around the island, 2) to study the bioaccumulation of pesticide in this species and 3) to define if lionfish could be used as sentinel species.

2. Material and methods

2.1. Samplings

The present study was carried out in Guadeloupe (16°15′N; 61°34′W), Lesser Antilles (Fig. 1). Samplings were conducted during two surveys: in 2013 with the help of professional fishers and in 2014. During both surveys, 97 lionfish were captured with spear guns or fish pots. Fish were collected within ten marine areas (from G01 to G10), previously marked out for the implementation of the European DCE ("Directive Cadre de l'Eau"). These marine areas have been described as homogeneous water masses according to various criteria as the morphology of the coasts, hydrology or hydrodynamic conditions (Fig. 1). Each fish sample was characterized by its geographical location (GPS coordinates). Wet weight (in g) and total length (in cm) of each individual collected in 2014 were recorded before dissections. Fish samples were filleted with the skin, were then wrapped in aluminum foil and kept frozen until analyses.

2.2. Measures of the concentrations of chlordecone

The laboratory LABOCEA conducted the quantitative analyses of chlordecone. Chlordecone was extracted from homogenized samples tissues with a solution of organic solvents (hexane-acetone) and turned into chlordecone hydrate (hydrosoluble) in the presence of soda. The aqueous phase was rinsed with hexane to eliminate fats. Chlordecone was then reassembled in acid conditions, and extracted with a solution of hexane and acetone. Concentrations of chlordecone were quantified with liquid chromatography coupled to mass spectrometry in tandem (UPLC–MS/MS). The lower quantification limit with this method was

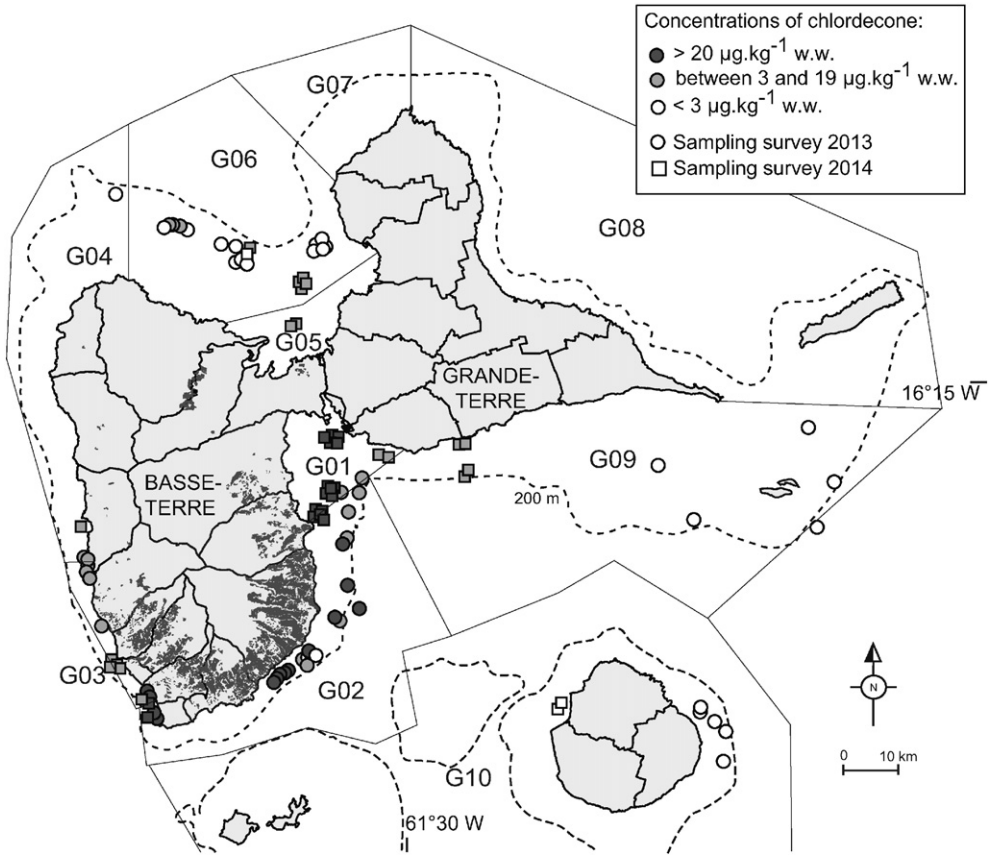

Fig. 1. Location of sampling areas (G01 to G10) and concentrations of chlordecone (in $\mu g.kg^{-1}$ w.w.) measured in lionfish during the study. Circles: sampled in 2013; squares: sampled in 2014. Black symbols: concentrations of chlordecone higher than 20 $\mu g.kg^{-1}$; gray symbols: concentrations between 3 and 19 $\mu g.kg^{-1}$; white symbols: concentrations inferior to 3 $\mu g.kg^{-1}$. Terrestrial areas in gray indicate contaminated soils due to previous bananas plantations.