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Ciguatera: A public health perspective

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ABSTRACT

Ciguatera fish poisoning is a seafood-borne illness caused by consumption of fish that have accumulated lipid-soluble ciguatoxins. In the United States, ciguatera is responsible for the highest reported incidence of food-borne illness outbreaks attributed to finfish, and it is reported to hold this distinction globally. Ciguatoxins traverse the marine food web from primary producers, *Gambierdiscus* spp., to commonly consumed fish in tropical and subtropical regions of the world. Ciguatoxins comprise 12 known congeners among Caribbean and tropical Atlantic fish and 29 reported congeners among Pacific fish. Expanding trade in fisheries from ciguatera-endemic regions contributes to wider distribution and increasing frequency of disease among seafood consumers in non-endemic regions. Ciguatoxins produce a complex array of gastrointestinal, neurological and cardiological symptoms. Treatment options are very limited and supportive in nature. Information derived from the study of ciguatera outbreaks has improved clinical recognition, confirmation, and timely treatment. Such studies are equally important for the differentiation of ciguatoxin profiles in fish from one region to the next, the determination of toxicity thresholds in humans, and the formulation of safety limits. Analytical information from case and outbreak investigations was used to derive Pacific and Caribbean ciguatoxin threshold contamination rates for adverse effects in seafood consumers. To these threshold estimates 10-fold safety factors were applied to address individual human risk factors; uncertainty in the amount of fish consumed; and analytical accuracy. The studies may serve as the basis for industry and consumer advisory levels of 0.10 ppb C-CTX-1 equivalent toxicity in fish from the tropical Atlantic, Gulf of Mexico, Caribbean, and 0.01 ppb P-CTX-1 equivalent toxicity in fish from Pacific regions.

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1. Introduction

Ciguatera fish poisoning is a food-borne disease endemic to tropical and subtropical coral reef regions of the world. It is contracted by consumption of finfish that have accumulated lipid-soluble toxins produced by microalgae (dinoflagellates) of the genus *Gambierdiscus*. The vectors and symptoms of this disease in the Caribbean and South Pacific have been described in the literature since the 18th century, with mentions of illness consistent with ciguatera dating back to the 16th century (e.g. Halstead, 1967). Current estimates of ciguatera prevalence in endemic regions range from less than 0.1% of populations of continental land masses (e.g., Queensland, Australia; Florida, USA) to greater than 50% of populations of small islands of the South Pacific and Caribbean (see reviews by Lewis, 1986a; Lange, 1994; Fleming et al., 1998, 2001). Ciguatera has over time become a hazard to consumers in non-endemic regions because of expanding international trade in seafood from tropical fisheries. In 2007, the European Union and the United States imported greater than 80% of their fishery products to meet consumer demand. In the U.S., approximately 2.4% of fishery imports originated from the islands of Oceania (excluding Australia and New

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Zealand) and 2.0% of fishery imports originated from tropical Atlantic and Caribbean sources (NMFS, 2008). Oceania and the tropical Atlantic and Caribbean encompass ciguatera-endemic regions and, consequently, the incidence of ciguatera disease in the continental U.S. has been linked to these sources. The recognition of ciguatera in non-endemic regions led public health institutions worldwide to rank ciguatera as the most common food-borne disease related to the consumption of finfish (De Fouw et al., 1999; Lehane, 2000).

On a global level, the collection of ciguatera epidemiological data has been inefficient. The public health impact of the disease is significantly underestimated because of a generalized reticence to report illness; this reflects the lack of conviction that anything can be done to cure the disease or ameliorate symptoms. In non-endemic regions, underreporting appears to result from the lack of diagnostic recognition of ciguatera poisoning by consumers and medical practitioners (McKee et al., 2001). It is estimated that less than 20% of ciguatera illnesses are reported. Lewis and Sellin (1992) estimated that over 25,000 people worldwide are affected annually by ciguatera. Fleming et al. (1998) ventured a broader estimate of 50,000–500,000 poisonings per year worldwide, while Tosteson (1995) suggested that 20,000–40,000 illnesses per year occur in Puerto Rico and the American Virgin Islands alone. The incidence and worldwide distribution of ciguatera is suggested to be on the increase (DeHaro et al., 2003; Levine, 1995; Lehane and Lewis, 2000; Poon-King et al., 2004), paralleling a worldwide increase in harmful algae bloom (HAB) events (Anderson, 1989; Hallegraeff, 1992, 1993; Lechuga-Deveze and Sierra-Beltran, 1995). Recent observations consistent with geographic expansion of ciguatera include the first reports of consumer illness and detection of ciguatoxic fish from the Canary Islands of the eastern Atlantic (Perez-Arellano et al., 2005), the western Gulf of Mexico (Villareal et al., 2007), and the eastern Mediterranean (Bentur and Spanier, 2007). Implicated meal remnants of the fish caught within the respective regions were confirmed to contain ciguatoxins and species of *Gambierdiscus* were identified from the respective coastal waters. Additional evidence consistent with expansion of ciguatera into new regions of the globe include observations of *Gambierdiscus* species at Crete Island (Aligizaki and Nikolaidis, 2008); Rio de Janeiro, Brazil (Nascimento et al., 2008); Cau Island, Viet Nam (The et al., 2008); and Hong Kong (Lu and Hodgkiss, 2004). It was suggested that HAB intensification and expansion are linked to anthropogenic (Ruff, 1989) and naturally occurring environmental changes, including global warming and increased nutrient loading (Smayda, 1989). Increases in sea surface temperature (SST) were associated with increased dinoflagellate abundance and fish toxicity in Puerto Rico (Tosteson et al., 1998; Tosteson, 2004). Chateau-Degat et al. (2005) reported a positive correlation between SST and *Gambierdiscus* abundance in Tahiti and used those data and human case incidence to develop a predictive model for disease. Several explanations were suggested for this relationship between elevated temperatures and increased ciguatera incidence, including the enhancement of denuded coraline substrates for *Gambierdiscus* through coral bleaching. Physical disturbances of coral reefs (e.g., dredging, harbor construction) were also associated with increased *Gambierdiscus* abundance (Lewis, 1986a; Bruslé, 1997) and outbreaks of ciguatera (Ruff, 1989; De Sylva, 1999). More recently, petroleum production platforms and state-sponsored artificial reef programs were shown to provide substrates that support coral and other components of the tropical benthos, including *Gambierdiscus* (Villareal et al., 2007). The introduced structures created new habitat in the upper euphotic zone and served as fish aggregation points, thereby accelerating toxin transfer from *Gambierdiscus* to prized food fish. The authors suggested that the structures could have unintended consequences for human health, particularly if rising SST over the next century alter benthic biota distributions and fish migration patterns. These concerns also extend to proposals for off-shore aquaculture operations or off-shore wind farms which would also add new substrate for benthic flora.

Although recognition of disease incidence in non-endemic regions has raised general concern, the public health and economic impacts of ciguatera have long existed and are particularly high in remote island nations and territories of the Pacific (Lewis, 1986b, 1992a, b) and Caribbean. Many of these affected communities are at marginal socioeconomic levels and fish represent an important source of protein and income. High disease incidence rates in some of the smaller islands of the South Pacific (Lewis, 1986a) and discouragement of commercial fisheries development due to the threat of ciguatera in export markets (e.g. Sadovy, 1999; Wong et al., 2005) significantly hinder human welfare in many small island communities. The risk of fish poisoning is broadly recognized by resident populations in endemic regions. In most cases, smaller reef fish are preferred because smaller fish are considered less likely to be poisonous. The odds are better for smaller fish to be less toxic or nontoxic, but smaller species and smaller specimens of apex predators can be as toxic as larger species of known repute. Island residents waste very little of the fish they catch when preparing meals (e.g., fish stew with head and viscera), a practice that negates the margin of safety sought by selection of the smaller species because of higher toxin concentrations in organ tissues. Many residents of the ciguatera-endemic Caribbean and Pacific consume subthreshold levels of toxin on a regular basis (e.g. Goodman et al., 2003; Glaziou and Martin, 1993). The toxins accumulate in their systems until that point where toxicity threshold is reached and symptoms appear. The afflicted then stop eating fish for a time, are treated using traditional remedies (e.g., Pink Pepper, *Schinus terebenthifolius*, in New Caledonia and Vanuatu; Bourdy et al., 1992; Garrec et al., 2005) and, when symptoms subside, they resume fish consumption.

While the distribution of ciguatoxic fish is often described as global between latitudes 35° north and 35° south, the actual locations of toxic fish within this broad geographic range are discrete and heterogeneous. There are many areas that are relatively free of ciguatera, that are often found in close proximity to areas of high risk for ciguatera. Lewis (2006) describes, for example, the southern reef of Tarawa and the western reef of Maraki in