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journal homepage: www.elsevier.com/locate/foodresEmerging ciguatera fish poisoning in the Archipelago of Madeira (Portugal): epidemiology and clinical profile[☆]Neide Gouveia^a, Viriato Timóteo^a, Sofia Cosme Ferreira^b, Pedro Reis Costa^{c,*}, Rita Câmara^b^a Laboratório Regional de Veterinária e Segurança Alimentar, Caminho das Quebradas de Baixo n.º 79, S. Martinho, 9000-254 Funchal, Portugal^b Serviço de Imunoalergologia, Hospital Central do Funchal Dr. Nêlio Mendonça, Funchal, Portugal^c IPMA-Portuguese Institute of the Sea and Atmosphere, Rua Alfredo Magalhães Ramalho 6, 1495-165 Lisbon, Portugal

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ABSTRACT

The expansion of ciguatera fish poisoning (CFP) into non-endemic regions, such as the Madeira Archipelago in the northeastern Atlantic Ocean, has raised significant concerns for public health and marine resource management. Since the first reported case in 2008, at least 55 cases of CFP have occurred in Madeira, despite the implementation of fishing bans targeting the most high-risk species. This study describes the epidemiological patterns and clinical manifestations of CFP in the region from 2007 to 2024, highlighting that not only apex predatory fish are associated with poisoning events. Cutaneous or mucocutaneous issues (itching), prominently pruritus, were reported in all cases. Gastrointestinal and neurological symptoms, especially diarrhoea, abdominal pain, paraesthesia-extremity and cold allodynia were among the very most frequent. On the other hand, cardiovascular manifestations were less common. The onset of the symptoms were generally reported within 24 h of food ingestion, and in some cases persisted up to 6 months. Results of this study also indicate an urgent need to further improve the management and control of this illness from an environmental perspective, involving the fisheries industry and recreational fishers, as well as from the perspective of the regional authorities responsible for public health and medical response.

1. Introduction

Ciguatera fish poisoning (CFP) is the most common seafood-borne illness worldwide, with particularly high incidence in tropical and some subtropical regions such as the Caribbean Sea, the South Pacific islands, and parts of the Indian Ocean. It is estimated to affect approximately 50,000 people each year, with locally high prevalence in endemic areas (Murray et al., 2025; Soliño & Costa, 2020). Ciguatera is caused by eating fish that carries ciguatoxins (CTX), with a natural origin in epiphytic dinoflagellate species of the *Gambierdiscus* and *Fukuyoa* genus. Ciguatoxins are lipophilic marine neurotoxins that act by binding to voltage-gated sodium channels (VGSCs), and impairing their inactivation, which results in persistent sodium influx, membrane depolarization, and neuronal hyperexcitability, ultimately disrupting normal sensory signaling (Nicholson & Lewis, 2006). The toxins enter the marine food web via herbivorous fish and are progressively transferred and biotransformed along the trophic levels and accumulated in fish top predators. More than 400 fish species been identified as CTX

vectors (Soliño & Costa, 2020).

Likely driven by changes in climate conditions, the expansion of ciguatera-associated dinoflagellates into new geographic areas may pose emerging risks to areas not historically affected. The first documented occurrences of ciguatera in non-endemic regions were reported in the early 2000s, with cases identified in the Canary Islands (Spain) in 2004 and in the Archipelago of Madeira (Portugal) in 2008 (Gouveia et al., 2009; Pérez-Arellano et al., 2005). The diagnosis of CFP is particularly challenging, as the condition presents with diverse clinical symptoms. The healthcare professionals in non-endemic areas are often unfamiliar with the disease, and standardized analytical methods for toxin confirmation remain unavailable. The clinical association established during the first confirmed case in Portugal in 2008 enabled the retrospective identification of fish poisoning incidents reported by nature wardens in the Selvagens Islands Marine Protected Area the previous year as cases of ciguatera poisoning (Costa et al., 2023; Gouveia et al., 2009).

The heterogeneous CFP clinical spectrum may include the following: 1) gastrointestinal symptoms such as dizziness, abdominal pain, nausea,

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vomiting, dehydration and severe diarrhoea), 2) neurological symptoms, namely paraesthesia including numbness and tingling in extremities (feet, hand and oral region of lips and tongue), fatigue, cold allodynia, and metallic taste, 3) cardiovascular manifestations include irregular pulse, hypotension, and bradycardia, whereas generalized symptoms commonly involve pruritus (itching) without urticaria or erythema, myalgia, arthralgia, headache, tremors, and severe perspiration, and 4) a wide range of other nonspecific symptoms (Arena et al., 2004; FAO, 2020; Friedman et al., 2008, 2017). Neuropsychological symptoms are also reported following the acute phase. While the evolution of the disease is typically benign, severe cases can lead to paralysis, coma, and even death (Friedman et al., 2017).

The key symptom distinguishing ciguatera from other fish-related disorders is cold allodynia, a thermal dysaesthesia where a normally innocuous cold stimulus triggers an unpleasant or painful “burning cold” sensation, tingling, or electric discharges (Friedman et al., 2017; Vetter et al., 2012). Ciguatoxins cause cold allodynia by making pain-sensing nerves overly excitable. They activate sodium channels in these neurons, which indirectly triggers cold-sensing pain pathways, leading to abnormal pain signals in response to mild cooling (Vetter et al., 2012). However, cold allodynia may be also experienced by patients suffering Neurotoxic Shellfish Poisoning (NSP), caused by the consumption of shellfish contaminated with brevetoxins, a group of compounds structurally similar to ciguatoxins, but produced by marine dinoflagellates of the *Karenia* genus. Although finfish can accumulate brevetoxins, human NSP cases have not been linked to their consumption. Consequently, when evaluating presumptive CFP patients with temperature dysaesthesia, a recent history of shellfish consumption suggests NSP as the more probable differential diagnosis (Friedman et al., 2017).

The severity and persistence of CFP symptoms depend on several factors, including the individual susceptibility or sensitivity connected with the physiological condition and the amount of toxin ingested and/or accumulated throughout life. Smoking has also been suggested as a potential risk factor for symptom persistence. CFP recurrence is linked to exposure to specific triggers, as symptoms may reappear in previously recovered patients following the consumption of certain foods (alcohol, marine/freshwater related products, pork, beef, chicken, nuts, canned products, dairy products, caffeine and chocolate), exposure to environmental factors (exposure to cold air and sun), or the enactment of specific behaviors (intense physical activity, dehydration, fatigue, lack of sleep, rapid weight loss and sexual intercourse) (FAO, 2020).

The mechanism underlying the long persistence of CFP symptoms remains unconfirmed, but two main mechanisms are hypothesized. The CTX storage in deep tissue with occasional release via lipid metabolism activation, and the involvement of immune dysregulation. Additionally, differences in symptomatology and persistence can be attributed to the presence of different ciguatoxin congeners (i.e., chemical structure variants) in fish from different geographic regions. In the Caribbean, the acute phase (i.e., within the first 12 h) is typically characterized by predominant gastrointestinal symptoms, followed by the onset of neurological manifestations. Conversely, in the Pacific, neurological symptoms may prevail during the acute stage, with rare reports describing severe neurological effects such as coma. In the Indian Ocean, CFP was associated with neurological, neuropsychiatric, and mental status alterations, with reports of hallucination, giddiness, incoordination, and loss of equilibrium. These symptoms appear to be specific of these regions (Friedman et al., 2017; Otero et al., 2010).

Ciguatera epidemiology is complex and indispensable for the management of marine resources in the future (Lehane & Lewis, 2000), since it represents a potential global health problem, especially in temperate regions like Europe. To minimise the risk of CFP in Madeira, and considering that neither an internationally validated method for CTX analysis nor certified standards are available, the Madeira Government has prohibited the capture and marketing of amberjacks (*Seriola* spp.) weighing more than 10 kg. This species is a top predator fish inhabiting Madeira Archipelago waters and has been the fish species mostly

Table 1

Number of outbreaks and cases of ciguatera fish poisoning (CFP) reported in Madeira Archipelago (Portugal) between 2007 and 2024.

Outbreak date	Number of cases	Hospitalized cases	Fish catch location	Place of consumption
Aug. 2007	1	0	Selvagem Islands sea	Selvagem Islands
Oct. 2007	1	0	Selvagem Islands sea	Selvagem Islands
Apr. 2008	3	0	Selvagem Islands sea	Selvagem Islands
May 2008	2	0	Selvagem Islands sea	Selvagem Islands
Jul. 2008	11	11	Selvagem Islands sea	Ship at sea
May 2010	5	3	Unknown	Household in Madeira
Jun. 2010	1	0	Unknown	Restaurant in Madeira
Jul. 2011	2	2	Unknown	Household in Madeira
Jun. 2012	16	12	Selvagem Islands sea	Ship at sea
Sept. 2015	7	4	Selvagem Islands sea	Restaurant in Madeira
Jul. 2023	2	1	Unknown	Restaurant in Madeira
Aug. 2024	4	4	Unknown	Household in Madeira
Total	55	37		

associated with CFP. The capture of groupers weighing more than 10 kg has also been banned, both to support stock conservation and to mitigate the associated risk of CFP. In the case of the Selvagens Islands, that seems to be a ciguatera hot-spot, a total ban of fishing has been issued under their status of marine protected area. Likewise the Madeira Government aims to protect seafood consumers and to comply with the EU directives that state that fishery products containing ciguatoxins must not be placed on the market (Costa et al., 2023). Nevertheless, despite of these measures, CFP cases continue to occur. The aim of this study is to report the emergence and epidemiology of ciguatera in the Madeira Archipelago.

2. Material and methods

2.1. The study area

The Madeira Archipelago is located in the northeastern Atlantic Ocean, approximately 700 km west of the African coast and 1000 km southwest of mainland Portugal. It comprises the heavily populated island of Madeira, as well as Porto Santo, and the lightly inhabited Desertas and Selvagens Islands. The Selvagens Islands, situated approximately 293 km southeast from Madeira Island, and 180 km north from Tenerife Island in the Canary Archipelago (Spain), are a marine protected area since 1971 and are considered a ciguatera hot spot. The Madeira archipelago lies within the influence of the Macaronesian biogeographic region and is characterized by subtropical oceanic conditions.

2.2. Data collection

This epidemiological study is based on voluntary interviews conducted within the community. A case was considered suspected ciguatera when individuals presented gastrointestinal and neurological symptoms, as described by FAO (2020), and these symptoms were associated with the consumption of locally caught high-risk fish species. A follow-up programme of fish poisoning outbreaks based voluntary interviews of individuals with a previous history of suspected ciguatera poisoning, between 2007 and 2024, was set up within the framework of

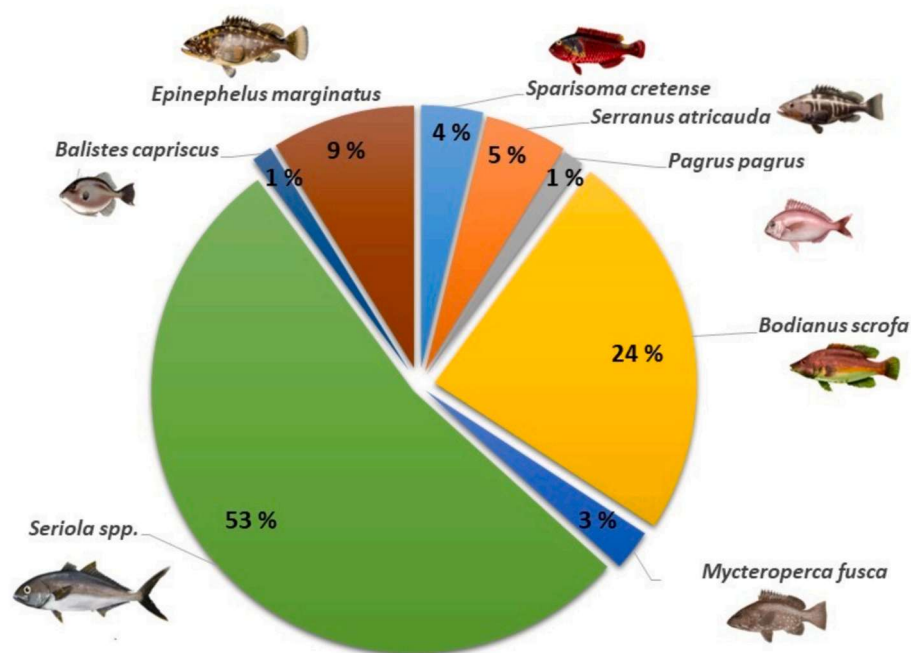


Fig. 1. Pie-chart indicating the relative frequency of the fish species associated with ciguatera poisoning in Madeira Archipelago (Portugal) between 2007 and 2024.

ciguatera's regional management and clinic diagnosis registration. A concise 3-pages questionnaire was developed to collect information on epidemiological aspects (date of poisoning, implicated fish species, commercial origin, specimen weight) and clinical characteristics, such as the onset, duration, and description of symptoms (27 symptoms were asked) (Supplementary Material).

3. Results

Since 2007, a total of 14 outbreaks have occurred in Madeira, with a total of 55 cases of ciguatera identified (Table 1). There is only no record of outbreaks in the years of 2009, 2013 and 2014. The episodes tended to occur during the warmest months of the year, spanning from spring to autumn (April to October). Amberjacks *Seriola spp.* ($n = 42$), were the main fish species implicated in CFP cases, but also other fish species with an intermediate position in the marine food web, such as red hogfish *Bodianus scrofa* ($n = 19$), dusky groupers *Epinephelus marginatus* ($n = 7$), blacktail comber *Serranus atricauda* ($n = 4$), parrotfish *Sparisoma cretense* ($n = 3$), island grouper *Mycteroperca fusca* ($n = 2$), and even a grey triggerfish *Balistes capriscus* ($n = 1$) and red porgies *Pagrus pagrus* ($n = 1$), were associated with CFP (Fig. 1).

The first outbreak recorded in Madeira occurred in July 2008, when a group of 11 fishermen showed typical symptoms of CFP after consumption of a 30 kg amberjack, caught around Selvagens Islands. This first incident highlighted that similar symptoms previously reported by nature wardens of the Selvagens Islands Natural Park after consuming locally caught fish were likely undiagnosed cases of CFP. In these previous cases, fish species were not limited to amberjacks *Seriola spp.* Other fish species, such as parrotfish, red hogfish, blacktail comber, grey triggerfish and red porgy were also implicated. Similarly, previous studies also associated fish with intermediate position in the marine food web with ciguatera poisoning cases (Haro et al., 2021).

In 2012, a group of fishermen, on a fishing boat, showed typical symptoms of CFP after consumption of an amberjack (about 20 kg) and a red hogfish (3–4 kg), caught in Selvagens Islands. Part of the crew had to be evacuated by helicopter. Later on 2015, at a restaurant a group of 14 friends had lunch a soup with several fish, however only those 7, who consumed dusky grouper (about 20 kg) got sick with CFP. The symptoms were more severe in those 4 who consumed the viscera (liver, gonads

and stomach) and the fish head.

The documented cases confirm the recurrent nature of CFP in the region. More recently, this continued threat has been reinforced by additional reports of suspected outbreaks, including those noted in July 2023 and August 2024 in the Madeira Archipelago, with the fish implicated identified as *Seriola spp.* The last outbreak occurred in 2024 and affected 4 patients, one of them presented to the emergency room with a severe case of fish poisoning. These recent episodes demonstrate that CFP is an ongoing issue and a current public health threat, requiring enhanced monitoring and risk assessment.

3.1. Population characterization

A total of 55 cases, over 14 outbreaks, were included in this analysis. This population included only adult patients, mostly male (92%) and with mean age of 54 years (minimum 32 years; maximum 82 years). The majority of the individuals were professionals linked to sea activities, such as fisherman, fish seller and nature wardens of the Selvagens Islands Natural Park.

Even though ciguatera fish poisoning presents a benign evolution, chronic symptoms may persist, as it is the case of one patient, from the 2024 outbreak, that remains with ongoing neurological symptoms, namely cold allodynia. This patient presented to the emergency room with a severe case of neurological symptoms and required intensive care. He had been consuming fish weekly throughout his life.

3.2. Clinical characterization

The majority of the study population reported cutaneous or mucocutaneous involvement (100%), prominently pruritus, followed by paraesthesia-extremity (89%), diarrhoea (89%), cold allodynia (87%) and prostration (80%). More than 50% of the individuals described muscle pain (78%), chills/sweating (58%), headache (56%), nausea (58%), vomiting ($n = 32$, 58%), abdominal pain (62%), tingling numbness (62%) and metallic taste (55%).

Cardiovascular involvement was present in only one third of the population. Other symptoms, such as insomnia (24%), joint pain (18%), pain or difficulty urinating (11%), difficulty breathing (11%), and difficulty speaking (9%) were expressed by a minority of patients. Full

Table 2

The most commonly reported clinical symptoms observed in ciguatera fish poisoning in Madeira Archipelago (Portugal) between 2007 and 2024.

Symptoms		N° of cases	Frequency (%)
General	Itching	55	100%
	Prostration	44	80%
	Muscle Pain	43	78%
	Chills/Sweating	32	58%
	Headache	31	56%
	Weight loss	27	49%
	Joint Pain	10	18%
	Difficulty breathing	6	11%
	Pain/difficulty urinating	6	11%
Gastrointestinal	Diarrhoea	49	89%
	Abdominal pain	34	62%
	Nausea	32	58%
	Vomiting	32	58%
Neurological	Paraesthesia-extremity	49	89%
	Cold allodynia	48	87%
	Tingling/numbness in mouth, tongue, teeth	34	62%
	Metallic taste	30	55%
	Loss of coordination	19	35%
	Insomnia	13	24%
	Anxiety/irritability/depression	9	16%
	Difficulty Speaking	5	9%
Cardiovascular	Hypotension	21	38%
	Bradycardia	16	29%
	Chest pain	16	29%

description of the study population and symptoms compatible with the diagnosis of CFP is shown in Table 2.

Hospitalization was required in 37 cases, and in two patients intensive care was observed, which were linked to the consumption of large amberjacks and dusky grouper, captured in the around the Selvagem Islands. The onset of symptoms was highly variable. However, gastrointestinal and cardiovascular symptoms were usually the first to appear. Neurologic involvement usually began within 24 h after fish ingestion. Nonetheless, these seem to be the more persistent, with potential to chronicity. Some patients remained with symptoms more than 6 months after fish ingestion. Even though ciguatoxins have not been confirmed in the fish consumed leftovers, the presence of ciguatoxins or toxicity in fish caught regionally was confirmed by rapid test kits, mouse bioassay (MBA), cell-based assay (CBA) and chemical analysis (Costa et al., 2018; Costa et al., 2021; Otero et al., 2010). More precisely, ciguatoxins was not detected in samples caught in Madeira Island coast but were detected in most fish caught in Selvagens Islands, even in the small fish from intermediate levels of the trophic chain (Costa et al., 2021).

4. Conclusions

With the evident climate changes, including a warming of seawater, the development and geographic expansion of dinoflagellates associated with ciguatera and subsequent contamination of the fish resources is expected. Therefore, an adequate and systematic monitoring of algae in waters of the Archipelago of Madeira and of the ciguatoxins presence in seafood should be implemented. This allows the development of control strategies to undermine this phenomenon.

As a result of the CFP cases, measures to prevent further outbreaks were taken, including fishing ban in Selvagens Islands to the depth of 200 m and ban on selling amberjacks with more than 10 kg in the entire Madeira archipelago. After the introduction of these precautionary measures, the CFP outbreaks have been registered more occasionally, usually related to fish consumption obtained outside the commercial circuit (sport fishing, recreational fishing and spearfishing) or through illegal activities, like fishing in forbidden areas of the Selvagens Islands. Although fatal cases are rare, CFP may cause a high degree of morbidity, as is seen in the present study. Given the persistent and debilitating

neurological symptoms, such as chronic cold allodynia, experienced by some patients, enhanced surveillance and coordinated public health effort are essential to reduce the long-term human morbidity associated with CFP in the region. The aftermath of ciguatera can also be associated with negative impacts on fisheries, and a substitution of fresh fish consumption with canned, salted, or meat products.

The existence of a multidisciplinary and multinational group is decisive in these emerging issues in order to achieve important goals, such as the increase in medical awareness for CFP, to better recognize the symptoms, improve reporting cases and outbreaks to fully elucidate the occurrence of CFP as many cases it may remain unreported.

CRedit authorship contribution statement

Neide Gouveia: Writing – original draft, Funding acquisition, Data curation, Conceptualization. **Viriato Timóteo:** Writing – original draft, Investigation, Data curation. **Sofia Cosme Ferreira:** Writing – original draft, Investigation. **Pedro Reis Costa:** Writing – review & editing, Funding acquisition, Conceptualization. **Rita Câmara:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.foodres.2026.118731>.

Data availability

Data will be made available on request.

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