CODEX ALIMENTARIUS COMMISSION

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World Health Organization

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Agenda Item 10 **CX/CF 23/16/10**
February 2023

JOINT FAO/WHO FOOD STANDARDS PROGRAMME

CODEX COMMITTEE ON CONTAMINANTS IN FOODS

16th Session
18-21 April 2023 (physical plenary meeting)
26 April 2023 (virtual report adoption)

DISCUSSION PAPER ON THE PREVENTION OR REDUCTION OF CIGUATERA POISONING

(Prepared by the Electronic Working Group chaired by
the United States of America and co-chaired by the European Union)

Codex members and observers wishing to submit comments on the recommendations put forward in paragraph 37 should do so as instructed in CL 2023/21-CF available on the Codex webpage[1]

INTRODUCTION

1. Ciguatoxins (CTXs) are a class of algal toxins produced by marine dinoflagellates. These toxins enter the food chain through consumption of CTX-containing algae by herbivorous fish and shellfish, and bioaccumulate in larger predatory fish. Ciguatera poisoning is an illness resulting from human consumption of marine organisms containing ciguatoxins. Ciguatera poisoning has become a global health issue and is increasing in prevalence due to factors that include climate change. Coastal communities that rely on local fishing as a food supply and as a source of income are particularly at risk from increasing occurrences of ciguatera poisoning.

2. The 15th Session of the Codex Committee on Contaminants in Foods (CCCF15, 2022), agreed to establish an electronic Working Group (EWG) chaired by the United States and co-chaired by the European Union to prepare a discussion paper on the development of a code of practice or guidelines to prevent or reduce ciguatera poisoning[2]. The EWG was asked to build upon the work already undertaken by the Food and Agriculture Organization of the United Nations (FAO) in collaboration with the International Atomic Energy Association (IAEA) and the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (IOC-UNESCO).[3]

3. The EWG was conducted via the Codex online forum. As a first step, EWG members were invited to contribute ciguatera literature references or other relevant material. The first draft of the paper was completed by the EWG chairs and posted to the online forum for comment; the paper was then revised by the Chairs. Due to time limitations, only one draft of the discussion paper was circulated for comment prior to sending the paper to the Secretariat.

4. The aim of this discussion paper is to present the background issues, approaches to prevention or reduction, and knowledge gaps and future challenges associated with ciguatoxins and ciguatera poisoning. Much of the information presented here was gathered from the *FAO/World Health Organization (WHO) Report of the Expert Meeting on Ciguatera Poisoning (Rome, 19–23 November 2018)*[4] but other sources of information were consulted (Appendix I). The information has been used to draft an outline for a possible future code of practice to prevent or avoid ciguatera poisoning (Appendix III). A project document to develop a CoP based on the information provided in the discussion paper is also presented for consideration by CCCF (Appendix II). A list of members and observers that joined the EWG can be found in Appendix V.

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1 Codex webpage/Circular Letters: http://www.fao.org/fao-who-codexalimentarius/resources/circular-letters/en/.
Codex webpage/CCCF/Circular Letters: http://www.fao.org/fao-who-codexalimentarius/committees/committee/related-circular-letters/en/?committee=CCCF

2 Regarding the title of the document, REP15/CF refers to "prevent and avoid" in paragraph 224 and "prevent and reduce" in paragraph 221. We are using the term "prevent and reduce" to be consistent with Codex practice.

3 REP15/CF22, paras. 219, 221, 224(ii)

4 Food and Agriculture Organization of the United Nations & World Health Organization. (2020). Report of the expert meeting on ciguatera poisoning: Rome, 19-23 November 2018. https://apps.who.int/iris/handle/10665/332640

APPENDIX I

DISCUSSION PAPER ON THE PREVENTION AND REDUCTION OF CIGUATERA POISONING
(For consideration by CCCF)

BACKGROUND

Ciguatoxins and Ciguatera Poisoning

1. Ciguatoxins (CTXs) are a class of algal toxins produced by benthic, epiphytic dinoflagellate species from the genera of *Gambierdiscus* and *Fukuyoa.* The algae grow best in tropical and subtropical marine environments with temperature ranges of approximately 25-31°C between the latitudes 35°N and 35°S. Cell density is greater in calm waters and near shallow reefs. Increases in CTXs in marine waters, followed by accumulation of toxins in predatory fish, are associated with blooms of *Gambierdiscus* and *Fukuyoa*. CTXs were initially categorized as belonging to one of three major classes that corresponded with their global location: Pacific (P-CTXs), Caribbean (C-CTXs), and Indian Ocean (I-CTXs). However, the FAO report recommends that toxin classes be categorized according to their chemical structure, i.e., Group 1 (CTX4-A analogues), Group 2 (CTX3-C analogues), Group 3 (C-CTX analogues) and Group 4 (I-CTX analogues). An example of CTX backbone structure CTX4-A is shown in Figure 1.

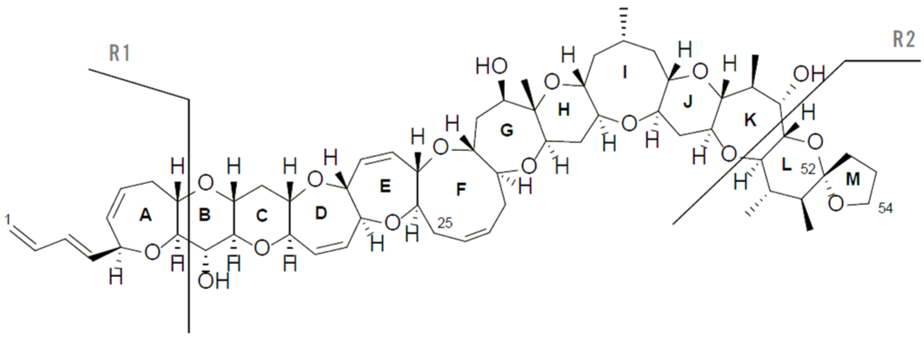

Figure 1. CTX4-A analogue backbone structure.[1]

2. CTXs have several characteristics that contribute to their stability and complexity. The toxin structures of some CTXs have been determined to be compound polyethers containing 13-14 fused rings. However, not all active compounds have been thoroughly characterized and structures are believed to vary depending on the strain of algae and location where it grows. CTXs are lipid-soluble, do not degrade under heat or mild pH changes, and are not known to be destroyed by cooking, freezing, or canning processes. They may undergo structural transformations as they are metabolized by marine organisms, often increasing in toxicity as they do so. More than 30 unique structures of toxin have been reported and many more have yet to be fully characterized.

3. CTXs enter the food chain through herbivorous marine fish and other marine organisms such as gastropods and bivalves that feed in marine reef environments and consume CTX-containing algae. Larger predatory fish accumulate toxins as they consume herbivorous fish, leading to bioaccumulation. Larger fish species or larger individuals in a population are not more likely to have accumulated CTX than smaller fish, as the diet of the fish plays a significant role. CTXs are lipophilic and concentrate in tissues such as heads, liver, viscera, and eggs (roe). More than 100 species of fish have been identified as having been contaminated with CTX, including barracuda, amberjack, grouper, and parrotfish. Many of these fish are territorial, which can help identify vulnerable fishing areas, though territories can overlap and change with time. CTX does not seem to be fatal to fish and there are no outward signs that a fish has CTX contamination, such as change in taste, odor, or texture; toxin analysis is required. CTX profiles from the Pacific region have been reported to differ between species of fish and areas from which they are harvested (e.g., CTX1-B in snappers and groupers vs. CTX4-A and CTX4-B in spotted knifejaw from Japanese waters). A list of fish species known to bioaccumulate CTXs is included in Appendix IV.

Health Effects

4. Humans experience ciguatera poisoning (CP) when they consume fish or other marine organisms contaminated with CTXs. The main biological targets of CTXs are the voltage gated sodium channels of neurons. Generally, the symptoms of CP are acute and appear within several hours of consuming contaminated food. They include cold allodynia, vomiting, diarrhea, bradycardia, muscle weakness, and dizziness; chronic symptoms have also been reported and are not well understood. Normally CP is not fatal but it can exacerbate the effects of any existing cardiovascular or nervous system health issues and result in death. A lowest observed adverse effect level (LOAEL) in humans has been estimated at 48.4 pg/kg bw CTX1-B equivalents based on data from the Caribbean region. There is no treatment for CP, but symptoms can be managed if the illness has been correctly identified.

5. Reports of CP have been made since the 1500s. Consuming CTX-contaminated fish was once limited to local residents and visitors in regions where toxic algae are known to accumulate in fish, but global trade of fish has caused CP illnesses to be reported by a wider range of countries. At present, CP is believed to be the most common type of marine biotoxin food poisoning worldwide. The global incidence rate of CP is estimated to be 10,000 to 50,000 cases per year, but the true rate is unknown because CP is often underreported by patients and health care professionals. Clinicians may not know all of the symptoms and may misdiagnose CP.

Surveillance and Testing

6. *Gambierdiscus* and *Fukuyoa* species are epiphytic dinoflagellates associated with benthic habitats and associated organisms (i.e. will grow near the bottom of an aquatic environment and attach themselves to substrates such as macroalgae and coral). Therefore, the typical methods of monitoring algae in the water column (such as when sampling harmful algal blooms) may not be appropriate. Because not all *Gambierdiscus* and *Fukuyoa* species produce CTX, and the correlation between algal species, fish contamination and human intoxication needs additional studies, speciation may be able to aid in assessing the risk of CP in the future. Speciation is recommended to be done in two stages: (1) optical microscopy as a screening tool and (2) scanning electronic microscopy (SEM) or molecular techniques as confirmation tools. FAO/WHO reported that routine testing of algae may serve as an early warning tool of increasing cell density for a particular area. Long term studies of population dynamics of these two algal genera are needed to help address seasonal variability.

7. Detection of CTXs in algal cultures, animal tissue, or human clinical samples can be performed using a number of techniques, each with differing sensitivities, advantages, and limitations:

   - Neuroblastoma assay (N2A): uses cell lines to measure a composite cytotoxicity via colorimetric assay. Detection is accomplished using MTT (reagent for measuring mitochondrial activity) or other types of reagents.
   - Receptor-binding assay (RBA): uses rat brain material and brevetoxin (Pbtx-3) as a competitive standard that has been conjugated with either a radiolabeled or fluorescent ligand. The RBA measures a composite affinity of CTX compounds to voltage gated sodium channels and allows estimation of CTX concentration.
   - Enzyme-linked immunosorbent assay (ELISA): sandwich format applicable to fish tissue and serum extracts. Currently this assay is only applicable to CTX from the Pacific region (CTX1-B and CTX3-B analogues)
   - Mouse bioassay (MBA): toxin extract is injected into mice and mice are observed for illness symptoms
   - Liquid chromatography/Mass spectrometry (LC-MS): separation of toxin congeners by LC column and quantitative determination of each congener by MS

8. Knowledge of the species of fish that may be linked to a CP case or outbreak can aid an epidemiological investigation. Some fish can be identified by their outward morphology, but this may not be possible for hybrid species and fish in commercial trade where heads or skin have been removed. Molecular techniques such as DNA barcoding can be used to determine the species of a fish with high confidence. Information on fish species can be used to determine if follow-up CTX testing on a sample is necessary and to help trace contaminated products back to their harvest site. Testing meal remnants for the presence of CTXs can also aid in linking CP with the source of the CTX, if remnants are available.

9. Because CTXs are complex and varied, and not all structures have been elucidated, it is not possible to successfully synthesize them for use as standards. CTXs must be collected from CTX-producing algae or extracted from contaminated fish or shellfish. The algae can be difficult to culture and grow slowly which means production of standards is often limited. It may be challenging to incorporate the radioactive labels needed for assays such as RBA. Toxin structures are reported to change when they are metabolized by different fish, and different standards may be needed based on the toxin profile observed This makes it very difficult to get the quantity of ciguatoxic fish material that is required from the isolation of these compounds.

SUMMARY OF WORK REPORTED BY INTERGOVERNMENTAL AGENCIES

10. The issue of CP has been raised at several international meetings in recent years, including an FAO-sponsored interagency meeting in 2015 and the 32nd Codex Committee on Fisheries and Fishery Products in 2016. In 2017, CCCF11 agreed to request scientific advice from FAO/WHO; specifically, to "carry out a risk assessment of ciguatera toxins and provide guidance for the development of risk management options; and to review existing analytical methods for ciguatoxin detection and quantification, with a view to recommending those useful for routine analysis and surveillance."

11. The work undertaken by FAO/WHO was summarized in the *FAO-WHO Report of the expert meeting on ciguatera poisoning (2018).* The report includes an evaluation of known CTXs, toxicological assessment and exposure assessment, geographic distribution, rate of illness, known congeners, methods of detection; and, based on this evaluation, guidance on the development of risk management options. Some conclusions reached by the expert meeting are as follows:

- It was not possible to complete a full risk assessment because of numerous existing data gaps. The limited number of cases and data prevented the panel from performing an exposure assessment or developing a complete guidance. Available animal and human data are insufficient to derive an acute reference dose.
- Analytical challenges: (i) there is a lack of internationally available certified CTX standards for the full spectrum of toxins; (ii) there is no certified reference material; (iii) there is no internationally validated protocol for CTX extraction from a biological matrix; and (iv) there is no internationally validated detection method. Because none of the current methods are completely validated, it is extremely difficult to compare methods and results between laboratories or agencies.
- Data from animal studies show that CTXs are efficiently absorbed and distributed throughout the body after ingestion and eliminated mainly through feces. Available human data concur with rapid ingestion and distribution of CTXs. CTXs may cross the placenta and enter breast milk.
- The expert meeting suggested that CTXs be classified by their chemical structure rather than geographical location. Effective risk management options would require definition of toxin profiles in each region, both in algal strains and in seafood, in order to establish risk evaluation protocols.

Building on the above-mentioned report, FAO, in collaboration with IAEA and IOC-UNESCO, developed an e-learning course on monitoring and preventing CP designed for food safety and fishery authorities, policy-makers, healthcare providers, and students (https://elearning.fao.org/course/view.php?id=648).

12. Intergovernmental bodies outside of FAO/WHO have formed organizations to aid in the development of resources for monitoring CTXs and CP. Some of the work being done by these organizations was referenced for this discussion and a brief summary is provided below:

- The IOC-UNESCO operates a HAB Programme and, for ciguatera, works on detection and sampling strategies for CTXs and CTX-producing organisms and on epidemiological data collection, reporting and assessments related to CP. See hab.ioc-unesco.org/ciguatera.
- The EuroCigua project performs ciguatera surveillance in the European Union (EU)/Economic European Area (EEA). See www.aesan.gob.es/AECOSAN/web/ciguatera/home/aecosan_home_ciguatera.htm
- The North Pacific Marine Science Organization ("PICES") has developed a project to build the capacity of local small-scale fishers and community members to monitor CP in their coastal ecosystems and fisheries and to share knowledge of detection and avoidance with similar ocean communities. See: https://www.pices.int/
- The IAEA, through its Technical Cooperation Program, supports projects to build capacity in HAB and ciguatera management in Latin America, the Caribbean, Africa, and Asia pacific through use of the RBA. See: https://www.iaea.org/services/technical-cooperation-programme.

KNOWLEDGE GAPS AND CHALLENGES

13. To be most effective at prevention or reduction of CP, many knowledge gaps and challenges should be addressed. Knowledge gaps and challenges can be categorized as: analytical methods and standards, human toxicology, monitoring and surveillance programs, climate change, and international cooperativity. These are explained in more detail below.

14. The analytical methods currently available for detection of CTXs are diverse and take advantage of different aspects of the toxins. Most are applicable to testing of algae or seafood tissues and have sufficient sensitivity needed to meet the health advisory levels but have not been validated. Analytical methods lack full validation mainly due to a lack of standards and reference materials. Support for production of standards will require an investment and cooperation at an international level.

15. Establishment of regulations or policies are dependent on a good understanding of the risk to human health. In general, the toxicology of CP is not well understood. Toxic equivalency factors (TEFs) have not been determined for the toxin congeners, which may vary depending on source location. Underreporting of cases by patients and health care providers makes it difficult to estimate CP prevalence and develop a full characterization of symptoms.

16. Monitoring programs are needed to assess the prevalence of CTX-producing algae in the environment and fish caught for harvest. More information is needed on how levels of dinoflagellates in coastal areas correspond to toxin levels in the food web, as well as how best to monitor for benthic algae (such as *Gambierdiscus*) vs. planktonic algae. There have been reports that toxicity may vary widely among fish schooling together and that CTX levels in fish may vary with the seasons. Surveillance of harvesting areas is possible but may be cost prohibitive; development and deployment of test kits can be expensive and may add to the cost of bringing fish to the consumer.

17. Surveillance programs have the potential to be great resources of information on CP; however, differences in reporting forms between regions or healthcare providers has made summarizing and analyzing the data difficult. Health authorities may use various detection methods and report CTX results in different units, regions may have different definitions for “serving sizes” of fish, and terminology may vary in how “outbreak” is defined. Awareness within the medical system plays a key role in clinical diagnosis. This is heightened as the global fish trade means countries/consumers are importing fish of tropical origin, and if intoxications do occur the symptoms are unfamiliar to medical staff. Experts have expressed that meal remnants are the best way to confirm illness, but these are often not available to test when CP is suspected.

18. The regions of optimal temperature conditions for growth of CTX-producing algae are expanding due to climate change and human activity. Climate change is likely to affect feeding behavior in fish and may have other unexpected effects as weather patterns change. The increasing number and severity of tropical storms can disrupt the local algae beds and distribute cells to areas that had previously not been associated with CP or alter the known toxin profile.

19. Some knowledge gaps and challenges can only be resolved through international cooperation. The names and terminology for commercial fish are not consistent between countries, which can lead to confusion when outbreaks are announced or if recalls are necessary. The criteria used to validate analytical methods may be different for each country, and some standards may not be available in all countries. Higher quality information and data on the global burden is needed, considering cases are underreported.

APPROACHES TO PREVENTION OR REDUCTION

20. Different types of programs may be used in conjunction to prevent or avoid CP. These include surveillance of harvest area waters, monitoring of sentinel or migratory fish species, measuring CTX levels in seafood for consumption or sale, hazard control plans and regulation of harvest and sale of fish, national illness/outbreak monitoring programs, guidance issued by national authorities, and management of human activities. These are discussed in detail below.

21. **Monitoring programs**. Monitoring programs can be used to determine the amount of contamination in a particular area and may be focused on algae or fish. Overall, the function of monitoring programs is to provide information that may be used to develop warnings of potential problems and provide warnings to the fishing industry or consumers against fishing in certain areas.

22. In marine waters, surveillance sampling can be used to positively identify algal blooms of *Gambierdiscus* or *Fukuoya* and characterize their toxin content. Passive sampling Solid Phase Adsorption Toxin Tracking (SPATT) devices can be used to collect toxins from water and have the potential to serve as an early warning tool. Monitoring approaches for benthic HABs, including sampling of blooms and determination of toxin profiles, are still being developed. Because toxin profiles may not be the same in toxins collected from algae versus toxins collected from fish and humans (due to metabolism), it is ultimately important to compare the CTX profiles to correlate environmentally sampled toxins to toxins isolated from fish and humans. FAO/WHO concluded that "effective and integrated risk management options would require definition of toxin profiles in each region, both in algal strains and in seafood to define risk evaluation protocols."

23. Monitoring may be undertaken with a two-tiered approach: initial test of algae or fish using a screening method such as N2A or RBA, then confirmation of any positive results using a quantitative method such as LC-MS. Monitoring programs are imperfect in that the concentration or profile of CTX in the environment does not always correlate to contamination in fish, and it may be impractical (i.e., costly and labor-intensive) to test fish to a sufficient degree for complete prevention of CP.

24. By monitoring aquatic environments for algal blooms and testing fish for CTX, it may be possible to develop a hazard map of areas where toxic algae grow and identify the species of fish that feed in those areas. Local officials can determine if there are sentinel species of fish that consume toxic algae and whether monitoring those fish as well as higher trophic fish that feed in the area is appropriate. It may be beneficial to determine the migratory patterns of local fish; some species of fish such as surgeonfish and grouper are known to exhibit high site fidelity. These maps may be useful to regulators when trying to determine if a harvest area needs to be closed to fishing by commercial firms or recreational fishermen.

25. **FSMS and HACCP plans**. Many national, regional, and local governments have developed regulations and voluntary guidance to ensure that CTX contaminated fish do not enter commerce. Depending on the point of application, these may include Food Safety Management Systems (FSMS) and Hazard Analysis and Critical Control Point (HACCP) plans. There may be limits on the areas or times where and when fish can be harvested, describe how monitoring will be conducted and how frequently, establish criteria for rejection of the commodity, and require an organized recordkeeping system. Developing a HACCP plan is based on understanding the location of the toxic areas for avoidance and/or emerging areas. HACCP plans include a hazard analysis; for CP, that would include local awareness of the types of fish harvested for food in a particular area which may be susceptible to CTX accumulation. Traceability of fish and accurate identification of the species being sold are also critical to FSMS plans, especially for fish that are intended for export, so that the processing or retail firm can confirm that the product was not harvested from a restricted area or is a restricted species. Some countries impose a size limit on harvest or sale of fish known to accumulate CTXs or require that fish above a size limit are tested for CTXs before sale. Because CTXs are known to accumulate in fish viscera, liver, heads, and roe, it is recommended that these organs or body parts are removed prior to sale and that fish production establishments have plans for how to dispose of those parts safely. Most FSMS plans require that processing establishments be inspected regularly to confirm that the HACCP-based procedures are being followed. FSMS aids manufacturers in ensuring they are compliant with food safety legislation and are producing products which are safe to consume.

26. **Surveillance and monitoring programs**. Surveillance programs that collect information about illnesses or outbreaks are operated by many national authorities and monitoring programs may include reports of CP or CTX detection. Ideally, the data collected by these programs with respect to CTX and CP would include the origin of contaminated fish, the fish species involved, the CTX congener profile, symptoms experienced by the patient, testing results from meal remnants, and other relevant information. Some examples of current monitoring programs that report information on CP are:

- USA/CDC National Outbreak Reporting System (NORS). NORS is a web-based platform used by local, state, and territorial health departments in the United States to report waterborne and foodborne disease outbreaks and enteric disease outbreaks transmitted by contact with environmental sources, infected persons or animals, or unknown modes of transmission. See https://www.cdc.gov/nors/index.html.

- EU/Rapid Alert System for Food and Feed (RASFF). RASFF is an online portal for the competent authorities of EU member states to support swift reaction by food safety authorities in case of risks to public health resulting from the food chain and make information available to consumers, business operators and authorities worldwide. See https://food.ec.europa.eu/safety/rasff-food-and-feed-safety-alerts.

- French Polynesia/Institut Louis Malardé (ILM). The Marine Biotoxin Laboratory of the ILM collects information from health clinics on patients with CP and issues an annual summary report. The secondary website provides maps of toxic areas and species that have been involved with poisonings for public awareness and research purposes. See www.ilm.pf, www.ciguatera.pf. The web-based platform Ciguawatch was recently released to encourage data sharing on ciguatera in the Pacific region. See https://ciguawatch.ilm.pf.

- Japan. All cases of suspected foodborne diseases, including CP, reported to local public health centers (PHCs) by physicians or patients are investigated by PHCs, and cases confirmed as foodborne diseases are notified to the Ministry of Health, Labour and Welfare (MHLW). Annual statistics and case summaries are available on the MHLW website. See www.mhlw.go.jp

- IOC-UNESCO operates the Harmful Algae Information System (HAEDAT), a database of multinational harmful algal events that have occurred in the North Atlantic and North Pacific regions since 2000. Records include information such as the reporting country, species of fish implicated, location of the fish harvest, related blooms and identification of algal strain. See www.haedat.iode.org.

- FAO/WHO International Food Safety Authorities Network (INFOSAN) facilitates the exchange of information regarding food safety events between its global members. INFOSAN receives information and requests for international assistance, as well as disseminates action alerts and best practices for implementation of risk management measures. See https://www.who.int/groups/international-food-safety-authorities-network-infosan

27. **Guidance developed by member countries**. Some countries have developed and published guidance on the levels of CTXs permitted in fish.

- For example, the U.S. has established a safety level of 0.1 ug/kg C-CTX-1 equivalents and 0.01 ug/kg P-CTX-1in finfish (primarily reef fish).[1]

- The Government of Canary Islands (Spain) has developed a protocol for management of wild-caught (non-aquacultured) fishery products susceptible to CP at the first point of sale.[2]

- The Ministry of Health, Labour and Welfare (Japan) prohibits the selling of *Sphyraena barracuda* and the import of certain species of fish susceptible to ciguatera contamination. Several local governments, where such fish species are often caught or have a huge wholesale market, provide administrative guidance on fish species and sizes which should be restricted from distribution or sale.

- In France, CP is included in the national outbreak monitoring programs: this includes the origin of contaminated fish, fish species involved, collection of meal remnants when possible, and symptoms experienced by ill people. Some French overseas territories have implemented management measures (regulation of harvest and sale of fish, with a list of forbidden species) based on outbreak cases:

    - Guadeloupe maintains a list of species that cannot be sold because of links to ciguatera cases. This list is currently being updated by analyzing fish remnants involved in CP cases in Guadeloupe and Martinique (DNA identification and CTX analysis).

    - Réunion maintains a list of species posing a risk of CP mainly based on historical reported outbreaks (last update 2009). This regulation considers these species and their origin (import or locally fished). Exceptions can be made on the basis of an analytical plan and health certificates from the exporting countries.

- The Ciguawatch platform (referred to in the previous section) includes information on management options, fish advisories, and sampling strategy

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1 FDA Fish and Fishery Products Hazards guide Appendix 5 https://www.fda.gov/food/seafood-guidance-documentsregulatory-information/fish-and-fishery-products-hazards-and-controls

2 Protocol For the Control of Ciguatoxins, Exotic and Invasive Alien Species in Fresh Extractive Fish Products https://www.gobiernodecanarias.org/cmsgobcan/export/sites/pesca/galerias/doc/Veterinario/Guia-Protocolo-Ciguat.-y-Exoticas-Rev.2.pdf

28. **Consumer advice**. Regional or local authorities can provide advice on fish species of concern and post warnings when fishing should be avoided. Raising awareness of the potential for CP in susceptible regions to the public (locals and tourists) has the potential to reduce the incidence of CP and also to help patients suffering from CP to correctly identify and report their illness. For example, in the U.S. state of Florida where CTXs are found, the state government provides a fact sheet to consumers that contains information on the susceptible fish species, symptoms of illness, and areas where CP has been documented.[3]

- The Government of Canary Islands (Spain) has developed advisory information for recreational fishermen, consumers, and a comic explaining the hazards for children.[4]
- The Institut Louis Malardé in collaboration with the Public Health Directorate of French Polynesia has developed educational materials for patients and health professionals. A guidebook on the more relevant CP-susceptible species per island group is also available. These materials are available through the Ciguawatch platform (www.ciguawatch.ilm.pf).
- In Japan, The Ministry of Health, Labour and Welfare and the Food Safety Commission have published a risk profile[5] and a fact sheet[6] on ciguatera. The Okinawa Prefectural Government has prepared a consumer pamphlet.[7]

29. **Control of human activity**. Some reports have noted that the increase in growth of *Gambierdiscus* can be correlated to changes in their local marine habitat. Loss of live coral reefs, overfishing of herbivorous fish species that graze on algae, and changes to ecosystems as a result of increased human activity can contribute to growth of toxic algae. Reducing the proliferation of artificial substrates that promote algae growth, controlling invasive predators, monitoring overfishing, and evaluating the impact of humans on the environment may reduce the prevalence of CP poisoning in the area.[8]

CONCLUSIONS

30. Although CP is complex and there are many knowledge gaps and challenges, possible topics for inclusion in a COP have been identified. The main points can be summarized as follows:

31. **Surveillance and monitoring programs**. Programs could include standardized practices for collection of samples, creation of temporal and geographic maps for algae and fish, establishment of a data repository of monitoring information, and issuance of reports and advisories to consumers. This information could be used by a variety of stakeholders (e.g. government officials, fish producers, and consumers) to avoid fish that may be contaminated with CTX.

32. **Analytical methods.** Sharing of reference materials, samples from different regions, and technology as well as collaborating on the validation of analytical methods (including protocols for CTX extraction) between regions is recommended. However, as analytical methods evolve over time, a recommendation of specific methods is not appropriate for a COP. International agencies such as IAEA and IOC-UNESCO are promoting such work and could be contacted for assistance.

33. **Harvesters and producers**. Firms involved with fish harvest or production could develop FSMS plans based on HACCP principles to reduce the chance of CTX-contaminated fish entering the marketplace. These plans could include inspection of fish processing plants and setting limits on size or source of fish, as well as traceability of fish products from harvest areas to retail, and criteria for rejecting shipments.

34. **Data sharing and training**. A unified global system for case and outbreak reporting could aid in developing strategies for reduction and prevention of CP. Countries could share their guidances or best practices with interested parties, including training of scientists in relevant methodology, especially for the benefit of coastal communities.

35. **Consumer advice**. Advisories could be posted in regions where fish that may contain CTX are harvested to alert consumers about fish species to be aware of, symptoms of CP, and directions on how to preserve meal remnants for testing. Healthcare professionals could be trained on how to recognize CP and how to notify the national database of CP illnesses.

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[3] Florida Fish and Wildlife Conservation Commission https://myfwc.com/research/redtide/general/poisoning-syndromes/
[4] Gobierno de Canarias, Consejeria de Agricultura, Ganaderia y Pesca https://www.gobiernodecanarias.org/pesca/temas/Control_calidad_productos/ciguatera.html)
[5] Ministry of Health, Labour and Welfare (https://www.mhlw.go.jp/topics/syokuchu/poison/animal_02.html)
[6] Food Safety Commission (https://www.fsc.go.jp/sonota/kikansi/38gou/38gou_3.pdf)
[7] Okinawa Prefecture (https://www.pref.okinawa.jp/site/hoken/eiken/kagaku/siguatera.html)
[8] Loeffler, C.R., et al. *Int. J. Environ. Res. Public Health* **2021**, *18*, 3027. https://doi.org/10.3390/ijerph18063027

36. **Control of human activity**. Countries can increase awareness of possible impacts on CTX-containing algae populations or contaminated fish resulting from changes to ecosystems, such as loss of live coral reefs, overfishing of herbivorous fish species, or increased human activity.

RECOMMENDATIONS

37. The EWG recommends CCCF to:

(i) Consider if new work should be proposed on a code of practice or if the EWG should revise the discussion paper for consideration by CCCF17. In case there is agreement to proceed with new work on the CoP, please consider the points below.

(ii) Review the proposal for new work in Appendix I.

(iii) Review the outline for the proposed COP in Appendix II.

(iv) Establish an EWG to prepare a proposed COP for the prevention and reduction of ciguatera poisoning based on the outline provided in Appendix II for consideration by CCCF17.

APPENDIX II

PROPOSAL FOR A NEW WORK ON A
CODE OF PRACTICE FOR THE PREVENTION OR REDUCTION OF CIGUATERA POISONING

PROJECT DOCUMENT

(For consideration by CCCF)

1) Purpose and scope of the project

The purpose of the proposed new work is to develop a code of practice (COP) or guidelines to prevent or reduce ciguatera poisoning based upon work already undertaken by the Food and Agriculture Organization of the United Nations (FAO) in collaboration with the World Health Organization (WHO), the International Atomic Energy Association (IAEA) and the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (IOC-UNESCO). Ciguatera poisoning has become a global health issue and is increasing in prevalence due to factors that include climate change. Coastal communities that rely on local fishing as a food supply and as a source of income are particularly at risk from increasing occurrences of ciguatera poisoning.

The scope of the work is to complete a COP to prevent or reduce ciguatera poisoning based on a discussion paper developed by an electronic Working Group (EWG) established in 2022.

2) Relevance and timeliness

In 2016, at the 32nd Session of the Codex Committee on Fisheries and Fishery Products, the Pacific Nations raised ciguatera poisoning as an issue that is increasingly affecting the tropical and subtropical regions of the Pacific Ocean, Indian Ocean, and Caribbean Sea between the latitudes of 35°N and 35°S. The issue of CP was raised at the 11th Session of the Codex Committee on Contaminants in Food (CCCF) in 2017. CCCF agreed to request scientific advice from FAO/WHO to enable the development of appropriate risk management options, resulting in the *2018 FAO/WHO Report of the Expert Meeting on Ciguatera Poisoning*. The 15th Session of the Codex Committee on Contaminants in Foods (2022) agreed to establish an EWG chaired by the United States and co-chaired by the European Union to prepare a discussion paper on the development of a code of practice or guidelines to prevent or reduce ciguatera poisoning. The EWG was asked to build upon the work already undertaken by the FAO in collaboration with the International Atomic Energy Association (IAEA) and the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (IOC-UNESCO).

3) Main aspects to be covered

This work will address measures for prevention or reduction of ciguatera poisoning including surveillance and monitoring programs, food safety management systems, data sharing, and consumer advice directed at various stakeholders such as government officials, fish harvesters and producers, healthcare professionals, and consumers.

4) Assessment against the criteria for establishment of work priorities

(a) **Consumer protection from the point of view of health and fraudulent practices**. To protect consumer health, exposure to ciguatera poisoning through consumption of contaminated seafood (e.g., fish) should be avoided. A COP providing recommendations to governments, fish harvesters and producers, healthcare professionals, and consumers will help prevent contaminated seafood from entering the marketplace and enable consumers to avoid contaminated products.

(b) Diversification of national legislations and apparent resultant or potential impediments to international trade. Currently, best practices and legislations. Development of a COP is needed to ensure that information on recommended practices for preventing and reducing ciguatera exposure is available to all member countries. It also will provide the means to enable exporters to ensure reduced risk of ciguatera poisoning and to assist in compliance with any MLs that may be established in the future.

(c) Scope of work and establishment of priorities between the various sections of the work.

The COP will address environmental measures, harvesting practices, safe production principles, government guidance and oversight, and consumer advice.

(d) **Work already undertaken by other international organizations in this field.** Work on ciguatera poisoning has been undertaken by several international organizations such as FAO, WHO, IOC-UNESCO, IAEA, EuroCigua, and the North Pacific Marine Science Organization ("PICES"), and can be consulted in development of a COP. These organizations have made recommendations but have not offered a COP.

5) Relevance to Codex Strategic Goals

(a) **Goal 1 Address current, emerging and critical issues in a timely manner.** Establishing a COP for prevention or reduction of ciguatera poisoning will address the current need for guidance to ensure the health of consumers.

(b) Goal 2 Develop standards based on science and Codex risk-analysis principles. This work will apply risk analysis principles in the development of a COP by using scientific data and recommendations from FAO/WHO and other recognized expert bodies to support a reduction in exposure of consumers to ciguatera poisoning.

(c) **Goal 3 Increase impact through the recognition and use of Codex standards.** The proposed COP ensures that information on recommended practices to prevent and reduce ciguatera poisoning consist of current best practices and are available to all member countries, especially those with fewer resources to devote to this topic.

(d) **Goal 4 Facilitate the participation of all Codex Members throughout the standard setting process.** Developing a COP through the Codex Step process will make information on recommended practices to prevent and reduce ciguatera poisoning available to all Codex members.

(e) Goal 5 Enhance work management systems and practices that support the efficient and effective achievement of all strategic plan goals. A COP will help ensure development and implementation of effective and efficient work management systems and practices by providing basic guidance for countries and producers to keep ciguatoxin-contaminated seafood out of the marketplace.

6) Information on the relationship between the proposal and other existing Codex documents

There is no known related Codex document.

7) Identification of any requirement for any availability of expert scientific advice

The FAO has already provided needed expert scientific advice in the form of the *2018 FAO/WHO Report of the Expert Meeting on Ciguatera Poisoning*.

8) Identification of any need for technical input to the standard from external bodies

Currently, there is no identified need for additional technical input from external bodies.

9) Timeline for completion of the new work

Work will commence following recommendation by CCCF and approval by CAC in 2023. Completion of work is expected by 2026 or earlier.

APPENDIX III

PROPOSED CODE OF PRACTICE FOR THE PREVENTION OR REDUCTION OF CIAGUATERA POISONING
– Outline –
(For consideration by CCCF)

Introduction

1. Ciguatoxins are a class of algal toxins produced by marine dinoflagellates. These toxins enter the food chain through consumption by herbivorous fish and bioaccumulate in predatory fish. Ciguatera poisoning is an illness resulting from human consumption of marine organisms containing ciguatoxins. Ciguatera poisoning has become a global health issue and is increasing in prevalence due to factors that include climate change. Coastal communities that rely on local fishing as a food supply and as a source of income are particularly at risk from increasing occurrences of ciguatera poisoning.

Recommended practices [These are only possible inclusions.]

2. Government-sponsored surveillance and monitoring programs

- Consider establishing or strengthening surveillance programs to monitor toxins in algae, sentinel fish species, and fish for consumption.
- When available, use standardized protocols for monitoring *Gambierdiscus* and *Fukuyoa* diversity (e.g., molecular approach vs. morphotaxonomy, how to approach inclusion of new species), or when collating epidemiological data.
- If data are available, government officials could create maps for stakeholders of the temporal and geographic toxin profiles of CTXs in the local area for both algae and fish. To be most useful, these maps may have to consider how the migratory patterns of reef fish may affect their toxin load (i.e., fish that migrate from an area with low *Gambierdiscus* density to one of high density) and be updated at a reasonable interval.
- Consider developing a national database to collect information on human illnesses and species or origin of the fish causing the illness if known (for countries reporting CP). Ensure that the database contains information on how much of the fish was consumed and definitions for "outbreak" (e.g., at least one person ill).
- Report the results of monitoring to stakeholders and post ciguatera warnings/fishing advisories in areas closed to harvesting.
- Government officials could develop policies related to CP and request that producers adhere to HACCP principles.

3. Analytical methods

- Because analytical technologies will continue to evolve, it is not appropriate to recommend any specific methods in a COP. Stakeholders are encouraged to contact their government officials for assistance or consult with international agencies such as IAEA on method development and sharing of technology.

4. Harvesters and producers

- Firms should consider adding CP to the FSMS plans, using HACCP principles, to reduce the likelihood of CTX-contaminated fish entering the marketplace. These could include inspection of fish processing plants, testing of commodities, and establishing criteria for rejecting shipments.
- It is recommended that primary seafood processors who purchase fish directly from fishermen obtain information about harvest locations to determine the potential for ciguatoxic fish based on knowledge of the regions where ciguatera occurs. Primary seafood processors should avoid purchasing fish species associated with causing CP from established or emerging areas linked with CP.
- Government officials could determine or identify the fish species and toxin maximum level (ML) that could cause a health risk locally or regionally, by conducting their own research or by using information developed in similar regions, and relay this information to harvesters or producers.
- Based on MLs determined by government officials, producers could set critical limits on harvest areas or other criteria appropriate for the toxin exposure in the local area.

5. Data sharing and training

- Agencies that have access to databases could share annual reports or other information summaries on monitoring or illnesses and could aid other regions in developing strategies for prevention and reduction of CP.
- If possible, based on data and reports, these agencies could make available guidance on consumption of fish associated with CP.

6. Consumer advice

- Be alert for advisories in regions where fish that may contain CTX are harvested either commercially or recreationally. Advisories could contain information about fish species to or fish sizes to avoid, symptoms of CP, and directions on how to preserve meal remnants for testing.
- Consumers should avoid eating fish from a restricted area. They should also limit the portion size of fish where the species have been linked to CP, and avoid eating liver, roe, head or viscera of any tropical marine fish.
- Healthcare professionals should be aware of the possibility of CP in patients, even in regions where CTX is not endemic but consumers may become ill from imported products. They can refer to materials with instructions on how to identify CP in patients and how to notify the national database of CP illnesses.

7. Minimizing negative impacts of human activity

- Based on surveillance monitoring, government officials could determine if loss of live coral reefs, overfishing of herbivorous fish species that graze on algae, and changes to ecosystems as a result of increased human activity are contributing to an increase of Gambierdiscus blooms or CTX-contaminated fish in the area, and if steps can be taken to decrease algae blooms or fish contamination.

APPENDIX IV

– Fish species known to harbor CTXs [1] -
(For information)

COMMON NAME	SCIENTIFIC NAME	LOCATION WHERE FISH WAS FOUND AND REFRENCE
Almaco jack / Kahala	*Seriola rivoliana*	Canary Islands (Perez-Arellano *et al*., 2005), Hawaii (Campora *et al*., 2008), Saint Thomas, Caribbean Sea (Granade, Cheng and Doorenbos, 1976)
Angelfish	*Pomacanthus imperator*	Kiribati (Mak *et al*., 2013)
Barracuda	*Sphyraena sp.*	California (Hokama, 1990)
Barracuda fish eggs	*Sphyraena sp.*	South Taiwan Province of China (Fenner *et al*., 1997)
Big-eye bream, emperor	*Monotaxis grandoculis*	French Polynesia (Bagnis *et al*., 1987), Enewetak Island (Randall, 1980), Kiribati (Mak *et al*., 2013)
Black forktail snapper	*Aphareus furca*	Hawaii (Hokama, 1990)
Black grouper	*Mycteroperca bonaci*	Key Largo, Florida, the United States of America (Dickey, 2008)
Black jack	*Caranx lugubris*	French West Indies (Pottier *et al*., 2002b, 2002a)
Blackfin snapper	*Lutjanus buccanella*	Saint Croix, United States Virgin Islands (Hoffman, Granade and McMillan, 1983)
Blacksaddled coral grouper	*Plectropomus laevis*	China, Hong Kong SAR (Wong *et al*., 2008)
Blotched javelin grunt	*Pomadasys maculatus*	Platypus Bay, Queensland, Australia (Hamilton *et al*., 2002a)
Blue sea chub (omnivorous)	*Kyphosus cinerascens*	French Polynesia, Tubuai (Australes), Nuku Hiva (Marquesas) (Darius *et al*., 2007), Enewetak Island (Randall, 1980)
Blue-barred parrotfish (herbivorous)	*Scarus ghobban*	French Polynesia, Tubuai (Australes) (Darius *et al*., 2007)
Bluefin trevally	*Caranx melampygus*	Nuku Hiva (Marquesas) (Darius *et al*., 2007), French Polynesia (Bagnis *et al*., 1987)
Blue-green snapper	*Aprion virescens*	French Polynesia (Bagnis *et al*., 1987), Enewetak Island, Bikini Island (Randall, 1980)
Bluelined surgeon fish (maiko) (herbivorous)	*Acanthurus nigroris*	Hawaii (Hokama, 1985)
Bluespine unicorn fish	*Naso unicornis*	Nuku Hiva (Marquesas) (Darius *et al*., 2007)
Blue-spotted grouper, roi	*Cephalopholis argus*	Nuku Hiva (Marquesas) (Darius *et al*., 2007), Hawaii (Campora *et al*., 2008), French Polynesia (Bagnis *et al*., 1987), Kiribati (Mak *et al*., 2013)
Bluestripe snapper (taape)	*Lutjanus kasmira*	Hawaii (Hokama, 1985)

[1] Food and Agriculture Organization of the United Nations & World Health Organization. (2020). Report of the expert meeting on ciguatera poisoning: Rome, 19-23 November 2018 https://apps.who.int/iris/handle/10665/332640.

COMMON NAME	SCIENTIFIC NAME	LOCATION WHERE FISH WAS FOUND AND REFRENCE
Brassy trevally	*Caranx papuensis*	French Polynesia, Tubuai (Australes) (Darius *et al*., 2007)
Butterflyfish	*Chaetodon auriga*	Kiribati (Mak *et al*., 2013)
	Chaetodon meyeri	Kiribati (Mak *et al*., 2013)
	Forcipiger longirostris	Kiribati (Mak *et al*., 2013)
Clown coris (wrasse)	*Coris aygula*	French Polynesia, Tubuai (Australes) (Darius *et al*., 2007), Enewetak Island (Randall, 1980), Kiribati (Mak *et al*., 2013)
Cone snails	*Conus spp.*	Hawaii (Kohli, Farrell and Murray, 2015)
Coral cod / coral grouper	*Cephalopholis miniata*	Fiji (Dickey, 2008; Arnett and Lim, 2007), Arafura Sea, Australia (Lucas, Lewis and Taylor, 1997)
Coral trout / leopard coral grouper	*Plectropomus sp.*	Great Barrier Reef, Australia (Hamilton *et al*., 2002a), French West Indies (Pottier *et al*., 2002b, 2002a)
	Plectropomus leopardus	French Polynesia, Tubuai (Australes) (Darius *et al*., 2007), China, Hong Kong SAR (Wong *et al*., 2005), Tahiti (Pompon and Bagnis, 1984), French Polynesia (Bagnis *et al*., 1987), Enewetak Island (Randall, 1980)
	Plectropomus melanoleucus	Enewetak Island (Randall, 1980)
	Plectropomus truncatus	Enewetak Island (Randall, 1980)
Dogtooth tuna	*Gymnosarda unicolor*	Nuku Hiva (Marquesas) (Darius *et al*., 2007), French Polynesia (Bagnis *et al*., 1987), Enewetak Island (Randall, 1980)
Dussumier's surgeon fish (palani) (herbivorous)	*Acanthurus dussumieri*	Hawaii (Hokama, 1985)
Ember parrotfish (herbivorous)	*Scarus rubroviolaceus*	Nuku Hiva (Marquesas) (Darius *et al*., 2007)
Epaulette soldier fish (squirrelfish)	*Myripristis kuntee*	Hawaii (Hokama, 1985)
Farmed salmon (omnivorous)	*Oncorhynchus kisutch*	Chile (Ebesu, Nagai and Hokama, 1994)
Filament-finned parrotfish (herbivorous)	*Scarus altipinnis*	French Polynesia, Tubuai (Australes) (Darius *et al*., 2007)
Fringelip mullet (omnivorous)	*Crenimugil crenilabis*	Nuku Hiva (Marquesas) (Darius *et al*., 2007), French Polynesia (Bagnis *et al*., 1987)
Gastropod	*Tectus niloticus*	French Polynesia (Gatti *et al*., 2018)
Giant clam (herbivorous)	*Tridacna maxima*	New Caledonia, French Polynesia (Roué *et al*., 2016)
	Hippopus hippopus	Vanuatu (Roué *et al*., 2016; Kohli, Farrell and Murray, 2015)
Giant grouper	*Epinephelus lanceolatus*	China, Hong Kong SAR (Wong *et al*., 2009)

COMMON NAME	SCIENTIFIC NAME	LOCATION WHERE FISH WAS FOUND AND REFRENCE
Giant trevally (ulua)	*Caranx ignobilis*	dice
Goatfish	*Parupeneus bifasciatus*	Kiribati (Mak *et al*., 2013)
Goldstriped goatfish	*Mulloidichthys auriflamma*	Hawaii (Hokama, 1990)
Great barracuda	*Sphyraena barracuda*	Bahamas (O'Toole *et al*., 2012), Cameroon (Bienfang, Oben and DeFelice, 2008), Florida Keys, the United States of America (Dechraoui *et al*., 2005), French West Indies (Pottier *et al*., 2003), Saint Barthélemy, Caribbean Sea (Vernoux and Abbad el Andaloussi, 1986; Kohli, Farrell and Murray, 2015), Guadeloupe (Pottier, Vernoux and Lewis, 2001), French Polynesia (Bagnis *et al*., 1987)
Greater amberjack / Kahala	*Seriola dumerili*	Canary Islands, Madeira Archipelago (Otero *et al*., 2010), Hawaii (Hokama, Banner and Boylan, 1977; Hokama, Abad and Kimura, 1983; Campora *et al*., 2008), Haiti (Poli *et al*., 1997), Saint Barthélemy, Caribbean Sea (Vernoux and Abbad el Andaloussi, 1986), Saint Thomas, Caribbean Sea (Granade, Cheng and Doorenbos, 1976)
Green moray eel	*Gymnothorax funebris*	Saint Barthélemy, Caribbean Sea (Vernoux and Abbad el Andaloussi, 1986)
Grey snapper	*Lutjanus griseus*	French West Indies (Pottier *et al*., 2002b, 2002a)
Hawaiian monk seal	*Monachus*	Hawaii (Bottein *et al*., 2011)
Hawkfish	*Paracirrhites hemistictus*	Kiribati (Mak *et al*., 2013)
Heavy beak parrotfish (herbivorous)	*Scarus gibbus*	French Polynesia (Satake *et al*., 1996), Tahiti (Pompon and Bagnis, 1984), French Polynesia (Bagnis *et al*., 1987), Enewetak Island (Randall, 1980)
Horse-eye jack	*Caranx latus*	French West Indies (Pottier *et al*., 2002b, 2002a), Saint Barthélemy, Caribbean Sea (Vernoux and Lewis, 1997; Lewis, Vernoux and Brereton, 1998), Bahamas (Larson and Rothman, 1967), Saint Thomas, Caribbean Sea (Granade, Cheng and Doorenbos, 1976)
Humpback red snapper	*Lutjanus gibbus*	Nuku Hiva (Marquesas) (Darius *et al*., 2007), French Polynesia (Bagnis *et al*., 1987), Enewetak Island, Bikini Island (Randall, 1980)
Humpback unicorn fish	*Naso brachycentron*	Nuku Hiva (Marquesas) (Darius *et al*., 2007)
Humphead wrasse	*Cheilinus undulatus*	French Polynesia (Bagnis *et al*., 1987), China, Hong Kong SAR (Wong *et al*., 2005), Enewetak Island (Randall, 1980)
Jellyfish (omnivorous)	*Cnidaria sp.*	American Samoa (Zlotnick *et al*., 1995)
King mackerel "Coronado" (king fish) (omnivorous)	*Scomberomorus cavalla*	Florida, the United States of America (Dickey, 2008), Saint Barthélemy, Caribbean Sea (Pottier, Vernoux and Lewis, 2001; Vernoux and Abbad el Andaloussi, 1986), Guadeloupe (Pottier, Vernoux and Lewis, 2001)

COMMON NAME	SCIENTIFIC NAME	LOCATION WHERE FISH WAS FOUND AND REFRENCE
Large grouper	*Epinephelus fuscoguttatus*	Enewetak Island (Randall, 1980), Kiribati (Mak *et al*., 2013)
	Epinephelus hoedtii	Enewetak Island (Randall, 1980)
	Epinephelus maculatus	Enewetak Island (Randall, 1980)
	Epinephelus tauvina	Bikini Island (Randall, 1980), Kiribati (Mak *et al*., 2013)
	Epinephelus coeruleopunctatus	Kiribati (Mak *et al*., 2013)
	Epinephelus multinotatus	Kiribati (Mak *et al*., 2013)
	Epinephelus polyphekadion	Kiribati (Mak *et al*., 2013)
	Epinephelus spilotoceps	Kiribati (Mak *et al*., 2013)
	Cephalopholis argus	Enewetak Island (Randall, 1980), Kiribati (Mak *et al*., 2013)
	Variola louti	Enewetak Island (Randall, 1980), Kiribati (Mak *et al*., 2013)
	Pagrus pagrus	Selvagens Islands (CarlosIII, 2017)
Lesser amberjack	*Seriola fasciata*	Selvagens Islands (Madeira Archipelago) (Otero *et al*., 2010), West Africa (Canary Islands) (Boada *et al*., 2010)
Lionfish	*Pterois volitans*	Virgin Islands (Robertson *et al*., 2014)
	Pterois spp.	Guadalupe, Caribbean (Solino *et al*., 2015)
Lobster	*Panulirus penicillatus*	Kiribati (Mak *et al*., 2013)
Longface emperor bream	*Lethrinus olivaceus*	Nuku Hiva (Marquesas) (Darius *et al*., 2007)
Lyretail	*Variola albimarginata*	China, Hong Kong SAR (Wong *et al*., 2008)
Mangrove red snapper	*Lutjanus argentimaculatus*	China, Hong Kong SAR (Wong *et al*., 2008)
Marble grouper	*Epinephelus microdon*	French Polynesia (Bagnis *et al*., 1987), Enewetak Island, Bikini Island (Randall, 1980)
Marbled spinefoot rabbitfish (herbivorous)	*Siganus rivulatus*	Eastern Mediterranean (Bentur and Spanier, 2007)
Misty grouper	*Epinephelus mystacinus*	Saint Thomas, Caribbean Sea (Granade, Cheng and Doorenbos, 1976)
Moorish idol	*Zancius cornutus*	Kiribati (Mak *et al*., 2013)
Moray eel	*Gymnothorax javanicus*	Tuamotu Archipelago and Tahiti (French Polynesia) (Murata *et al*., 1990; Legrand *et al*., 1989; Labrousse and Matile, 1996), Tarawa, Kiribati, central Pacific Ocean (Chan *et al*., 2011; Lewis and Jones, 1997), Hawaii (Scheuer *et al*., 1967), Kiribati (Mak *et al*., 2013)

COMMON NAME	SCIENTIFIC NAME	LOCATION WHERE FISH WAS FOUND AND REFRENCE
	Gymnothorax flavimarginatus	Kiribati (Mak *et al*., 2013)
Mullet (herbivorous)	*Mugil cephalus*	(Ledreux *et al*., 2014)
One-spot snapper	*Lutjanus monostigma*	Nuku Hiva (Marquesas) (Darius *et al*., 2007), Enewetak Island, Bikini Island (Randall, 1980)
Ophiuroids (brittle stars) starfish (omnivorous)	*Ophiocoma spp.*	Hawaii (Kohli, Farrell and Murray, 2015)
Orangeband surgeon fish (naenae) (herbivorous)	*Acanthurus olivaceus*	Hawaii (Hokama, 1985)
Orangespine unicorn fish	*Naso lituratus*	Nuku Hiva (Darius *et al*., 2007), (Marquesas) (Bagnis *et al*., 1987)
Orange-spotted grouper	*Epinephelus coioides*	China, Hong Kong SAR (Wong *et al*., 2005)
	Epinephelus spp.	Canary Islands (CarlosIII, 2017)
Pacific slopehead parrotfish (herbivorous)	*Chlorurus frontalis*	French Polynesia, Tubuai (Australes) (Darius *et al*., 2007)
Parrotfish	*Hipposcarus longiceps*	Kiribati (Mak *et al*., 2013)
	Scarus ghobban	Kiribati (Mak *et al*., 2013)
	Scarus russelii	Kiribati (Mak *et al*., 2013)
Pickhandle barracuda	*Sphyraena jello*	Hervey Bay, Queensland, Australia (Lewis and Endean, 1984a)
Porcupinefish	*Diodon liturosus*	Kiribati (Mak *et al*., 2013)
	Diodon hystrix	Kiribati (Mak *et al*., 2013)
Pufferfish	*Arothron nigropunctatus*	Kiribati (Mak *et al*., 2013)
Rabbitfish (herbivorous)	*Siganus argenteus*	Kiribati (Mak *et al*., 2013)
Red emperor	*Lutjanus sebae*	Mauritius (Nazareth, Saya de Malha, Soudan) (Hamilton *et al*., 2002b; Hamilton *et al*., 2002a)
Red grouper	*Epinephelus morio*	Saint Barthélemy, Caribbean Sea (Vernoux and Abbad el Andaloussi, 1986)
Sabre squirrelfish	*Sargocentron*	Nuku Hiva (Marquesas) (Darius *et al*., 2007)
Sand tilefish	*Malacanthus plumieri*	Saint Barthélemy, Caribbean Sea (Vernoux and Abbad el Andaloussi, 1986)
Sawtail grouper	*Mycteroperca prionura*	Baja California, Mexico (Sierra-Beltran *et al*., 1997)
Sea cucumber (herbivorous)	*Holothuria spp.*	Hawaii (Park, 1999; Kohli, Farrell and Murray, 2015)

COMMON NAME	SCIENTIFIC NAME	LOCATION WHERE FISH WAS FOUND AND REFRENCE
Sea urchin	*Tripneustes gratilla*	French Polynesia (Darius *et al*., 2018a)
Shark	*Carcharhinus leucas*	Madagascar (Diogene *et al*., 2017)
	Carcharhinus amblyrhinchos	Enewetak Island (Randall, 1980)
	Carcharhinus limbatus	Enewetak Island (Randall, 1980)
	Lycodontis javanicus	Enewetak Island (Randall, 1980)
	Sphyraena barracuda	Enewetak Island (Randall, 1980)
Sleek unicorn fish	*Naso hexacanthus*	Nuku Hiva (Marquesas) (Darius *et al*., 2007)
Small grouper	*Epinephelus merra*	Kiribati (Mak *et al*., 2013)
Snapper	*Lutjanus fulvus*	Kiribati (Mak *et al*., 2013)
	Lutjanus spp.	Antigua (Hokama, 1990), Okinawa, Japan (Yogi *et al*., 2011), West Africa (Bienfang, Oben and DeFelice, 2008), Baja California, Mexico (Kohli, Farrell and Murray, 2015), Saint Thomas, Caribbean Sea (Granade, Cheng and Doorenbos, 1976)
	Macolor niger	Enewetak Island (Randall, 1980), Kiribati (Mak *et al*., 2013)
	Caranx ignobilis	Enewetak Island (Randall, 1980)
	Caranx lugubris	Enewetak Island (Randall, 1980)
	Caranx melampygus	Enewetak Island (Randall, 1980)
	Hipposcarus harid	Enewetak Island (Randall, 1980)
Soldier fish	*Myripristis berndti*	Kiribati (Mak *et al*., 2013)
Spanish hogfish	*Bodianus rufus*	Saint Barthélemy, Caribbean Sea (Vernoux and Abbad el Andaloussi, 1986), Hawaii (Hokama, 1990)
Spanish mackerel (omnivorous)	*Scomberomorus commerson*	Hervey Bay, Queensland, Australia (Lewis and Endean, 1984a), (Lewis and Endean, 1984a, 1983)
Spotted knifejaw (omnivorous)	*Oplegnathus punctatus*	Miyazaki, Japan (Yogi *et al*., 2011)
Spotted unicorn fish	*Naso brevirostris*	Nuku Hiva (Marquesas) (Darius *et al*., 2007)
Squaretail coral grouper	*Plectropomus areolatus*	China, Hong Kong SAR (Wong *et al*., 2005)
Squirrelfish	*Sargocentron tiere*	Kiribati (Mak *et al*., 2013)
Star snapper	*Lutjanus stellatus*	China, Hong Kong SAR (Wong *et al*., 2008)]
Starfish	*Ophidiaster ophidianus*	Madeira, Azores (Silva *et al*., 2015)
	Marthasterias glacialis	Madeira, Azores (Silva *et al*., 2015)
Steephead parrotfish (herbivorous)	*Chlorurus microrhinos*	French Polynesia, Tubuai (Australes) (Darius *et al*., 2007)

COMMON NAME	SCIENTIFIC NAME	LOCATION WHERE FISH WAS FOUND AND REFRENCE
Striped bristletooth surgeon fish (herbivorous)	*Ctenochaetus striatus*	Nuku Hiva (Marquesas) (Darius *et al*., 2007), Tahiti (Bagnis *et al*., 1985a)
Surgeonfish (herbivorous)	*Acanthurus lineatus*	Kiribati (Mak *et al*., 2013)
	Acanthurus maculiceps	Kiribati (Mak *et al*., 2013)
Surgeonfish (omnivorous)	*Acanthurus gahhm*	Kiribati (Mak *et al*., 2013)
	Acanthurus nata	Kiribati (Mak *et al*., 2013)
	Acanthurus striatus	Kiribati (Mak *et al*., 2013)
Tarry hogfish (a'awa)	*Bodianus bilunulatus*	Hawaii (Hokama, 1985)
Thinlip grey mullet (omnivorous)	*Liza vaigiensis*	Nuku Hiva (Marquesas) (Darius *et al*., 2007), Miyazaki, Japan (Yogi *et al*., 2011)
Trevally (ulua, papio)	*Caranx sp.*	Hawaii (Hokama, 1985, 1990)
Triggerfish	*Balistapus undulatus*	Kiribati (Mak *et al*., 2013)
Trumpet emperor bream	*Lethrinus miniatus*	French Polynesia (Bagnis *et al*., 1987)
	Lethrinus miniatus	Enewetak Island (Randall, 1980)
	Lethrinus callopterus	Enewetak Island (Randall, 1980)
Twosaddle goatfish	*Parupeneus insularis*	Nuku Hiva (Marquesas) (Darius *et al*., 2007)
Two-spot red snapper (red bass)	*Lutjanus bohar*	Mauritius (Hamilton *et al*., 2002b; Hamilton *et al*., 2002a), Minamitorishima (Marcus) Island, Japan (Yogi *et al*., 2011), French Polynesia, Tubuai (Australes) (Darius *et al*., 2007), Nuku Hiva (Marquesas) (Darius *et al*., 2007), Hawaii (Hokama, 1990), French Polynesia (Bagnis *et al*., 1987), Enewetak Island, Bikini Island (Randall, 1980), Kiribati (Mak *et al*., 2013), India, Indonesia, Viet Nam (Friedemann, 2019)
Whitebar surgeonfish	*Acanthurus*	French Polynesia
Wrasse	*Epibulus insidiator*	Kiribati (Mak *et al*., 2013)
Yellow goatfish	*Mulloidichthys martinicus*	Saint Barthélemy, Caribbean Sea (Vernoux and Abbad el Andaloussi, 1986)
Yellowfin grouper	*Mycteroperca venenosa*	Guadeloupe and Saint Barthélemy, Caribbean Sea (Pottier, Vernoux and Lewis, 2001)
	Mycteroperca fusca	Canary Islands (CarlosIII, 2017)
	Pamatomus saltatriz	Canary Islands (CarlosIII, 2017)
Yellowfin surgeon fish (herbivorous)	*Acanthurus xanthopterus*	Hawaii (Hokama, 1990), Nuku Hiva (Marquesas) (Darius *et al*., 2007)

APPENDIX V

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