Review Article: Ciguatoxic Potential of Brown-Marbled Grouper in Relation to Fish Size and Geographical Origin

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Abstract. To determine the ciguatoxic potential of brown-marbled grouper (*Epinephelus fuscoguttatus*) in relation to fish size and geographical origin, this review systematically analyzed: 1) reports of large ciguatera outbreaks and outbreaks with description of the fish size; 2) Pacific ciguatoxin (P-CTX) profiles and levels and mouse bioassay results in fish samples from ciguatera incidents; 3) P-CTX profiles and levels and risk of toxicity in relation to fish size and origin; 4) regulatory measures restricting fish trade and fish size preference of the consumers. P-CTX levels in flesh and size dependency of toxicity indicate that the risk of ciguatera after eating *E. fuscoguttatus* varies with its geographical origin. For a large-sized grouper, it is necessary to establish legal size limits and control measures to protect public health and prevent overfishing. More risk assessment studies are required for *E. fuscoguttatus* to determine the size threshold above which the risk of ciguatera significantly increases.

INTRODUCTION

Ciguatera is caused by eating reef fishes containing ciguatoxins (CTXs).^{1,2} Large outbreaks and ciguatoxic fishes are mainly found in tropical and subtropical regions of the Pacific Ocean, Indian Ocean, and Caribbean Sea, between the latitudes 35°N and 35°S.^{1,2} Because of growing reef fish trade and demand, international tourism and abundance and distribution of the *Gambierdiscus* species,^{1–3} the global incidence of ciguatera and the populations at risk are expected to increase.

In the Pacific Ocean region, the incidence and epidemiology of ciguatera are relatively well described in the Pacific Islands, Australia, Japan, Hong Kong, and other coastal cities of southern China.^{4–8} In other coastal countries of East Asia and Southeast Asia, only isolated cases or small case series are identified.⁹ CTX in the Pacific (P-CTX) is the most potent.¹ Avoidance of large predatory reef fishes are generally recommended.^{2,10,11}

In this review, the main objective is to determine the ciguatoxic potential of brown-marbled grouper (*Epinephelus fuscoguttatus*) in relation to fish size and geographical origin.

LITERATURE SEARCH

To identify journal articles and other relevant publications, a search of Medline (1980 to 28 May 2015), China Journal Jet (1994 to May 2015) and Google Scholar was performed, using ciguatera, ciguatoxins, brown-marbled grouper and *E. fuscoguttatus* as the keywords. Where fish size in total length was specified, the weight was estimated, and vice versa.¹²

CIGUATERA OUTBREAKS

Large ciguatera outbreaks and outbreaks with description of the fish size are summarized in Table 1.

In Hong Kong, *E. fuscoguttatus* > 5 kg accounted for most of the 12 ciguatera outbreaks in early May 1998.¹³ During 2007–2009, there were 32 outbreaks caused by *E. fuscoguttatus* and other species (size: 0.6–3.0 kg).¹⁴

In the coastal cities of Fujian Province and Guangdong Province in China, there were eight published case series.^{15–23} In Foshan and Zhongshan, there were three large outbreaks (affecting > 100–200 subjects) after eating *E. fuscoguttatus* served at banquets.^{16,22,23} In Xiamen and Shantou, large *E. fuscoguttatus* caused the outbreaks, as indicated by size of fish (> 7 kg) and left-over portions (~5 kg).^{15,18,19} The size of *E. fuscoguttatus* and other fishes responsible for the outbreaks in Huizhou, Yangjiang, and Zhongshan was smaller (4.5, 2.0–4.3, and 1.5–2.5 kg, respectively).^{20,21}

P-CTX profiles and levels and mouse bioassay (MBA) results in *E. fuscoguttatus* samples from ciguatera outbreaks are summarized in Table 2.

In Australia, an *E. fuscoguttatus* sample from ciguatera outbreak in Queensland contained P-CTX-2 and P-CTX-3 as the main congeners, with P-CTX-1 at a lower level of 0.3 µg/kg fish flesh.^{24,25}

In Japan, an *E. fuscoguttatus* sample from ciguatera outbreak in Okinawa was confirmed to be toxic (0.1 MU/g fish flesh).²⁶ Another *E. fuscoguttatus* sample was found to contain mainly CTX-1B, with MBA result of 0.13 MU/g.²⁷

WILD-CAUGHT *E. FUSCOGUTTATUS*

P-CTX profiles and levels in wild-caught *E. fuscoguttatus* and risk of toxicity in relation to fish size and geographical origin are summarized in Table 3.

In Japan, *E. fuscoguttatus* from Okinawa waters was found to contain CTX-1B (the main toxin), 54-deoxyCTX-1B and 52-epi-54-deoxyCTX-1B.²⁸ Moreover, 5 (20.8%) of the 24 *E. fuscoguttatus* collected from the coasts were toxic.²⁹ The size dependence of toxicity was obvious since all five toxic fishes were > 70 cm in total length (> 13.3 kg).

In Kiribati, all three *E. fuscoguttatus* from Marakei were toxic when analyzed by mouse neuroblastoma assay (P-CTX-1 equivalent 0.2, 2 and 3 µg/kg).²⁹ Of 171 fish (58 species) from Marakei and Tarawa tested, 91% were toxic (P-CTX-1 equivalent > 0.01 µg/kg). Carnivores (particularly groupers and moral

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TABLE 1
Ciguatera outbreaks after eating *Epinephelus fuscoguttatus*

City	Period	Details
Hong Kong ¹³	May 1998	12 outbreaks ($n = 40$), mostly caused by <i>E. fuscoguttatus</i> > 5 kg
Hong Kong ¹⁴	September 2007	32 outbreaks ($n = 102$), <i>E. fuscoguttatus</i> and other fishes, usually 0.6–3 kg‡
Xiamen ¹⁵	February 2005	3 outbreaks ($n = 29$), after eating <i>E. fuscoguttatus</i> portions, large fish size as reflected by left-over portions of ~5 kg, 16 subjects hospitalized
Foshan ^{16*} †	November 2004	1 outbreak ($n > 100$), after eating <i>E. fuscoguttatus</i> in banquet§, 44 subjects admitted to this hospital
Huizhou ¹⁷	October 1997	1 outbreak ($n = 7$), after eating <i>E. fuscoguttatus</i> (4.5 kg), mainly head and belly (0.9 kg), 6 subjects hospitalized (5 for 5–10 days and 1 for > 20 days with the most severe symptoms after eating fish head)
Shantou ^{18,19*} †	August 2004	1 outbreak ($n = 64$), after sharing 2 <i>E. fuscoguttatus</i> (> 7 kg each), all 64 subjects hospitalized, concomitant alcohol consumption (39% of subjects) increased the risk of CV features and altered skin sensation
Yangjiang ^{20*}	April 2005–December 2008	4 outbreaks, after eating <i>E. fuscoguttatus</i> , humphead wrasse or leopard coral grouper, 2.0–4.3 kg‡, 17 subjects with CV features hospitalized
Zhongshan ^{21*}	April 1994–December 2003	86 out of 358 subjects with CV features, after eating <i>E. fuscoguttatus</i> , sea bass or leopard coral grouper, 1.5–2.5 kg‡, 28 (85%) men drank alcohol
Zhongshan ^{22*} †	November 2004	1 outbreak, after eating <i>E. fuscoguttatus</i> in banquet§, 132 subjects admitted to this hospital
Zhongshan ^{23*} †	November 2004	1 outbreak ($n > 200$), after eating <i>E. fuscoguttatus</i> in a banquet§, 63 subjects admitted to this hospital

CV = cardiovascular.

*References ⁸ for details on signs and symptoms.

†References ¹¹ for details on signs and symptoms.

‡Size referred to all the fish species listed.

§ % of subjects with alcohol consumption not mentioned; CV features = hypotension and bradycardia.

eels) were more toxic than omnivores and herbivores; fishes from Marakei were more toxic than fishes from Tarawa.³⁰ Two wild-caught *E. fuscoguttatus* contained P-CTX-1 1.35–1.40 µg/kg flesh (0.80–0.87 µg/kg by a conventional method).³¹ In two *E. fuscoguttatus* from Marakei, total P-CTX in flesh was 0.13–3.1 µg/kg (P-CTX-1 ~54%).³²

In New Caledonian, based on the expert assessments and published reports, the ciguatoxic potential of *E. fuscoguttatus* was considered medium; the size (total length) threshold above which the risk of ciguatera significantly increases was 40 cm (1.0 kg).³³

REGULATORY MEASURES AND FISH SIZE PREFERENCE

There are limited data on the regulatory measures restricting the sales, export, or import of *E. fuscoguttatus* and fish size preference of the consumers (Table 4).

In Australia, Department of Agriculture and Fisheries, Queensland has drawn up a list of protected and no-take fish

TABLE 2

P-CTX and MBA results in *Epinephelus fuscoguttatus* samples from ciguatera outbreaks

Country	Details
Australia	
Queensland ²⁴	*†Mainly P-CTX-2 and P-CTX-3 (P-CTX-1 at a lower level)
Queensland ²⁵	*†P-CTX-1 0.3 µg/kg flesh (P-CTX-2 and P-CTX-3 also detected)
Japan	
Okinawa ²⁶	†Toxicity of flesh 0.1 MU/g
Okinawa ²⁷	†‡CTX-1B in flesh (§52-epi-54-deoxyCTX-1B also detected); toxicity 0.13 MU/g

CTX = ciguatoxin; MBA = mouse bioassay; P-CTX = Pacific ciguatoxin.

*Probably an identical sample.

†Based on the results of 1 sample.

‡P-CTX-1 also known as CTX-1B.

§Potency ~50% of CTX-1B as tested by MBA.²⁸

species.³⁴ For *E. fuscoguttatus*, the legal size limits were set at 50–70 cm.

The Sydney Fish Market, the largest center of fish distribution in Australia, rejected fish from high-risk regions (e.g., Kiribati and Marshall Islands) and set maximum size limit for high-risk species—10 kg for *E. fuscoguttatus*.³⁵ Large fish (> 6 kg) were often considered unpalatable due to fears of possible ciguatera.³⁶

In the Pacific Islands, live reef fish from Kiribati caused a serious ciguatera outbreak in Hong Kong and a ban on export (including *E. fuscoguttatus*) was imposed in 2004.³⁷

TABLE 3

P-CTX and MBA results in *Epinephelus fuscoguttatus* from different regions

Country	Details
Japan	
Okinawa ²⁸	* CTX-1B (also 54-deoxyCTX-1B, 52-epi-54-deoxyCTX-1B) in flesh
Okinawa ²⁹	5 (20.8%) out of 24 samples from the coasts were toxic when tested by MBA (4 with 0.025 and 1 with 0.05 MU/g flesh); all 5 toxic fishes were > 70 cm in total length and > 13.3 kg in weight
Kiribati	
Marakei ³⁰	All 3 wild-caught samples were toxic (mouse neuroblastoma assay)
Marakei, Tarawa ³¹	2 wild-caught samples contained P-CTX-1 1.35–1.40 µg/kg flesh
Marakei ³²	2 wild-caught samples contained total P-CTX 0.13–3.1 µg/kg flesh (P-CTX-1 ~54%), the 8.2 kg fish contained total P-CTX 3.1 µg/kg flesh
New Caledonia ³³	Size threshold for ciguatoxicity 40 cm (1.0 kg), based on assessment by the local experts and published reports; all 5 specimens (100%) in the local market were significantly above the this size threshold

CTX = ciguatoxin; MBA = mouse bioassay; P-CTX = Pacific ciguatoxin.

*11 fish samples collected from Okinawa waters over 10 years.

TABLE 4

Trade restrictions on *Epinephelus fuscoguttatus* and fish size preference of the consumers

Country	Details
Australia	
Queensland ³⁴	Legal size limits—50 cm (2.0 kg) minimum, 70 cm (5.6 kg) maximum
Sydney fish market ³⁵	Maximum size limits – Queensland (10 kg), Pacific countries (10 kg); All warm water ocean fish* from Kiribati and Marshall Islands prohibited
Commercial fishers ³⁶	Difficulty in selling fish > 6 kg (consumers fear of possible ciguatera)
Kiribati ³⁷	No export of live reef food fish*
New Caledonian ³³	Fish > 40 cm (1 kg) should be banned from the local market
Hong Kong ³⁸	Consumers preferred < 1.8 kg (< 48 cm) for better taste and safety

*Including *E. fuscoguttatus*, which is native to the Pacific Islands.

In New Caledonian, a ban on fish > 40 cm (1 kg) from the local market was recommended, after considering the size threshold for ciguatoxicity and prevalence of specimens in the local market with a size larger than the threshold of risk.³³

In Hong Kong, *E. fuscoguttatus* < 1.8 kg was more popular because the risk of toxicity was assumed to be lower and plate-sized fish was considered the best for consumption.³⁸

In Mauritius (Indian Ocean), the sales of *E. fuscoguttatus* and 16 other species were not allowed.³⁹

DISCUSSION

Epinephelus fuscoguttatus can grow to a maximum size of > 100 cm total length (> 17.1 kg).⁴⁰ The most common size found in live food fish market in Hong Kong in 1995–1996 was 35–40 cm (6.8–10.2 kg), with a range of 15–90 cm (0.5–12.0 kg).⁴¹

Epinephelus fuscoguttatus can cause ciguatera, especially if CTX-rich fish parts (head, viscera, roe, and skin), larger fish from high-risk areas and greater quantities are eaten.¹¹ Concomitant consumption of alcohol may increase the risk of severe ciguatera.^{8–11} In both the Pacific and Atlantic, it has long been known that fishes most likely to contain CTX include *E. fuscoguttatus*.⁴² It was responsible for numerous ciguatera incidents in the Pacific Islands,³⁹ Australia,⁵ Japan^{9,43} and, in recent decades, Hong Kong and other coastal cities of southern China.^{7,8,11} The emerging number of reports of ciguatera, particularly large outbreaks, in both exporting and importing countries necessitates control measures to restrict consumer exposure to *E. fuscoguttatus* (Table 4). To the consumers, the fishing industry and the regulatory authorities, the common task is to define region-specific size threshold for *E. fuscoguttatus*, above which the ciguatera risk markedly increases. Size restrictions on *E. fuscoguttatus* smaller than the maturity length are also necessary to prevent overfishing.⁴⁴

Hong Kong and other coastal cities of southern China are the major importers of live reef food fish.^{8,38,41} *Epinephelus fuscoguttatus* served at banquets can cause large ciguatera outbreaks, and small- to extra-large *E. fuscoguttatus* can be ciguatoxic (Table 1). *Epinephelus fuscoguttatus* is a large-sized grouper, with the minimum commercial size limit of 40.5–50 cm (1.06–2.0 kg).^{34,44} If fish of the minimum size limit is regarded as small, the fish responsible for the outbreaks in Table 1 can be called small to extra large. In ban-

quets, whole plate-sized fish cooked by steaming is normally served. Small-sized *E. fuscoguttatus* (40.5–50 cm) had probably been served^{16,22,23} because bigger fish would cost more and pose practical problems in cooking and serving for dozens of tables at the same time. The possibility of worsening of symptoms by concomitant alcohol ingestion at banquets could not be excluded.

There was very limited data on P-CTX profiles and levels in *E. fuscoguttatus* implicated in previous ciguatera outbreaks (Table 2). P-CTX was responsible for such outbreaks in the Pacific region; P-CTX profiles in *E. fuscoguttatus* were region-specific. In Queensland, mainly P-CTX-2 and P-CTX-3 (each with 30% potency of P-CTX-1)⁴⁴ were found, together with a P-CTX-1 level of 0.3 µg/kg.^{24,25} In Okinawa, mainly CTX-1B (P-CTX-1) was found, together with 52-epi-54-deoxyCTX-1B.²⁷

It is estimated that the lowest P-CTX-1 level associated with mild toxicity is 0.1 µg/kg fish flesh, and ingestion of ~1.0 µg/kg of P-CTX-1 will produce clear toxic symptoms.⁴⁵ An uncertainty factor of 10 is applied to the lowest level associated with mild symptoms (0.1 µg/kg) to derive a “safe” level of P-CTX-1 equivalent 0.01 µg/kg fish, which should not exert effects in sensitive subjects when eating a single fish meal.⁴⁵

The region-specific P-CTX profiles were confirmed also in wild-caught *E. fuscoguttatus*. In Japan, fish from Okinawa was found to contain CTX-1B (the main toxin), 54-deoxyCTX-1B and 52-epi-54-deoxyCTX-1B, suggesting that the local *Gambierdiscus* species only produced CTX-1B type of toxins.²⁷ In Kiribati, fish from Marakei contained P-CTX-1 (the main toxin), P-CTX-2 and P-CTX-3.³² P-CTX-1 equivalent toxicity tested by mouse neuroblastoma assay also varied with the fish species (*E. fuscoguttatus* and other carnivores > omnivores > herbivores) and the origins (Marakei > Tarawa).³⁰ Thus, increase in P-CTX-1 levels along the food chain from herbivores to carnivores was seen.

In Kiribati, the higher P-CTX levels in five out of the seven wild-caught *E. fuscoguttatus* should be noted: two with P-CTX-1 equivalent 2–3 µg/kg,³⁰ two with P-CTX-1 1.35–1.40 µg/kg,³¹ and one (8.2 kg) with total P-CTX 3.1 µg/kg fish flesh (P-CTX-1 ~54%).³²

In quantifying size dependency of ciguatoxicity, two different approaches were used. In Okinawa, 24 *E. fuscoguttatus* from the coasts were tested by MBA and five (20.8%) were found to be toxic (≥ 0.025 MU/g flesh).²⁹ All five toxic fishes were > 70 cm (> 13.3 kg), whereas none of the 12 fishes 40–60 cm (1.0–3.5 kg) were toxic.²⁹ In New Caledonian, expert assessments and published reports were used to define the size threshold (40 cm or 1.0 kg) above which the risk of ciguatera significantly increased.³³ So far, P-CTX levels and size dependency of toxicity in wild-caught fish indicate that the risk of ciguatera after eating *E. fuscoguttatus* varies with geographical origin.

Regulatory measures restricting fish trade should protect public health and minimize overexploitation of *E. fuscoguttatus*, while consumers' preference may reflect their perceived risk (Table 4). In Australia, the legal size limits for *E. fuscoguttatus* were 50–70 cm.³⁴ The Sydney Fish Market set maximum size limit of 10 kg for *E. fuscoguttatus* (Queensland and Pacific countries), but would reject fish from high-risk areas (e.g., Kiribati and Marshall Islands).³⁵ Consumers regarded fish > 6 kg (71.5 cm) unpalatable due to fears of possible ciguatera.³⁶

In Kiribati, a ban on export of live reef food fishes (including *E. fuscoguttatus*) was imposed in 2004 following serious ciguatera outbreaks in Hong Kong.³⁷ In New Caledonian, the experts recommended a ban on fish > 40 cm (1 kg) from the local market.³³ In Hong Kong, consumers were even more cautious about the fish size (< 1.8 kg).³⁸ Thus, the perceived risk of ciguatera caused by *E. fuscoguttatus* and actions among the regulatory authorities, the trade and the consumers also varied with the size and origin of the fish.

To prevent ciguatera and take prompt actions during outbreaks, accurate information on reef fish species and their sources must be available. Traceability or the ability to trace the reef fishes upstream along the supply chain and downstream toward distribution and consumption is essential.⁴⁶

CONCLUSIONS

P-CTX levels in flesh and size dependency of toxicity indicate that the risk of ciguatera after eating *E. fuscoguttatus* varies with its geographical origin. P-CTX profiles also reflect the types of CTX produced by local *Gambierdiscus* species and accumulation along the food chain. For a large-sized grouper such as *E. fuscoguttatus*, it is necessary to establish legal size limits and control measures to protect public health and prevent overfishing. More risk assessment studies are required for *E. fuscoguttatus* to determine the size threshold above which the risk of ciguatera significantly increases.

Received June 15, 2015. Accepted for publication July 18, 2015.

Published online August 31, 2015.

Financial support: This work is supported by research funding from the Centre for Food and Drug Safety, Faculty of Medicine, the Chinese University of Hong Kong.

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REFERENCES

- Lewis RJ, 2006. Ciguatera: Australian perspectives on a global problem. *Toxicon* 48: 799–809.
- FAO, 2004. Ciguatera fish poisoning. *Marine Biotoxins*. FAO Food and Nutrition Paper 80. Rome, Italy: Food and Agriculture Organization of the United Nations, 185–218.
- Litaker RW, Vandersea MW, Faust MA, Kibler SR, Nau AW, Holland WC, Chinain M, Holmes MJ, Tester PA, 2010. Global distribution of ciguatera causing dinoflagellates in the genus *Gambierdiscus*. *Toxicon* 56: 711–730.
- Skinner MP, Brewer TD, Johnstone R, Fleming LE, Lewis RJ, 2011. Ciguatera fish poisoning in the Pacific Islands (1998 to 2008). *PLoS Negl Trop Dis* 5: e1416.
- Gillespie NC, Lewis RJ, Pearn JH, Bourke AT, Holmes MJ, Bourke JB, Shields WJ, 1986. Ciguatera in Australia. Occurrence, clinical features, pathophysiology and management. *Med J Aust* 145: 584–590.
- Toda M, Uneyama C, Toyofuku H, Morikawa K, 2012. Trends of food poisonings caused by natural toxins in Japan, 1989–2011. *Food Hyg Saf Sci. Shokuhin Eiseigaku Zasshi* 53: 105–120.
- Chan TYK, 2014. Epidemiology and clinical features of ciguatera fish poisoning in Hong Kong. *Toxins (Basel)* 6: 2989–2997.
- Chan TYK, 2015. Emergence and epidemiology of ciguatera in the coastal cities of southern China. *Mar Drugs* 13: 1175–1184.
- Chan TYK, 2015. Ciguatera fish poisoning in east Asia and southeast Asia. *Mar Drugs* 13: 3466–3478.
- Chan TYK, 2013. Ciguatera caused by consumption of humphead wrasse. *Toxicon* 76: 255–259.
- Chan TYK, 2014. Large outbreaks of ciguatera after consumption of brown marbled grouper. *Toxins (Basel)* 6: 2041–2049.
- Anonymous, 2014. *Length-Weight Parameters for Epinephelus fuscoguttatus*. Available at: <http://www.fishbase.org/PopDyn/LWRelationshipList.php?ID=4460&GenusName=Epinephelus&SpeciesName=fuscoguttatus&fc=289>. Accessed May 25, 2015.
- Department of Health, Health alert on consumption of big tiger grouper. Available online: http://www.dh.gov.hk/english/press/1998/14_05_98.html. Accessed May 25, 2015.
- Centre for Food Safety, 2010. *Food Safety Focus (Hong Kong), 51st Issue. Ciguatera Fish Poisoning*. Available at: http://www.cfs.gov.hk/english/multimedia/multimedia_pub/files/FSF51_2010-10-20.pdf. Accessed May 25, 2015.
- Luo HD, Bai YY, Zhou N, 2011. Study of three ciguatera fish poisoning cases in Xiamen city in 2005. *Chin J Prev Med* 45: 512–515.
- Wen YM, Wu GJ, 2007. Clinical analysis of ciguatera poisoning. *China Prac Med* 2: 74–75.
- Hong YF, Liu HB, Hu HS, Tian ZH, 1998. Case reports of poisoning caused by eating sea fish together. *Guangdong J Health Epidemic Prev* 24: 48–49.
- Chen SZ, 2005. First aid and nursing for 64 patients with colony ciguatera toxins poisoning. *Mod Hosp* 5: 78–79.
- Liao QG, Sui MS, Chen JP, 2005. Outbreak of ciguatoxin poisoning in 59 patients. *Chin J Emerg Med* 14: 663–666.
- Mo BX, Su YN, Yang JL, 2010. Cardioprotective effect on shenmai injection on ciguatera poisoning. *J Med Theor Prac* 23: 806–807.
- Zhong WJ, Wu GF, 2006. Ciguatera poisoning in patients with clinical manifestations of cardiovascular system. *New Chin Med* 37: 316–317.
- Hu YM, Chen WQ, Guan QX, Li X, 2005. Clinical analysis of 132 cases of ciguatera poisoning. *Chin J Intern Med* 44: 778–779.
- Liu ZX, Wei HC, Lin Z, Zhang XB, Song ZB, Wu YX, Meng JY, Tan XH, 2006. Clinical analysis of a collective ciguatoxin poisoning accident in a banquet. *China Trop Med* 6: 1689–1691.
- Stewart I, Lewis RJ, Eaglesham GK, Graham GC, Poole S, Craig SB, 2010. Emerging tropical diseases in Australia. Part 2. Ciguatera fish poisoning. *Ann Trop Med Parasitol* 104: 557–571.
- Stewart I, Eaglesham GK, Poole S, Graham G, Paulo C, Wickramasinghe W, Sadler R, Shaw GR, 2010. Establishing a public health analytical service based on chemical methods for detecting and quantifying Pacific ciguatoxin in fish samples. *Toxicon* 56: 804–812.
- Oshiro N, Sakugawa S, 2009. Food poisoning and consumer complaint cases caused by chemicals and natural toxins in Okinawa – FY2008. *Okinawa Inst Environ Health* 43: 181–184.
- Yogi K, Oshiro N, Inafuku Y, Hiram M, Yasumoto T, 2011. Detailed LC-MS/MS analysis of ciguatoxins revealing distinct regional and species characteristics in fish and causative alga from the Pacific. *Anal Chem* 83: 8886–8891.
- Yogi K, Sakugawa S, Oshiro N, Ikehara T, Sugiyama K, Yasumoto T, 2014. Determination of toxins involved in ciguatera fish poisoning in the Pacific by LC/MS. *J AOAC Int* 97: 398–402.
- Oshiro N, Yogi K, Asato S, Sasaki T, Tamanaha K, Hiram M, Yasumoto T, Inafuku Y, 2010. Ciguatera incidence and fish toxicity in Okinawa, Japan. *Toxicon* 56: 656–661.
- Chan WH, Mak YL, Wu JJ, Jin L, Sit WH, Lam JC, Sadovy de Mitcheson Y, Chan LL, Lam PK, Murphy MB, 2011. Spatial distribution of ciguateric fish in the Republic of Kiribati. *Chemosphere* 84: 117–123.
- Wu JJ, Mak YL, Murphy MB, Lam JCW, Chan WH, Wang M, Chan LL, Lam PKS, 2011. Validation of an accelerated solvent extraction liquid chromatography-tandem mass spectrometry method for Pacific ciguatoxin-1 in fish flesh and comparison with the mouse neuroblastoma assay. *Anal Bioanal Chem* 400: 3165–3175.
- Mak YL, Wai TC, Murphy MB, Chan WH, Wu JJ, Lam JCW, Chan LL, Lam PKS, 2013. Pacific ciguatoxins in food web components of coral reef systems in the Republic of Kiribati. *Environ Sci Technol* 47: 14070–14079.
- Clua E, Brena PF, Lecasble C, Ghnassia R, Chauvet C, 2011. Prevalence and proposal for cost-effective management of the ciguatera risk in the Noumea fish market, New Caledonia (South Pacific). *Toxicon* 58: 591–601.

34. Department of Agriculture and Fisheries, Queensland Government, 2014. *Size, Take and Possession Limits for Tidal Waters*. Available at: <https://www.daf.qld.gov.au/fisheries/recreational/rules-regulations/size-possession-limits-tidal>. Accessed May 25, 2015.
35. Sydney Fish Market Pty Ltd, 2005. *Schedule of Ciguatera High-Risk Areas and Species Size Limits*. Available at: http://www.sydneyfishmarket.com.au/Portals/0/Ciguatera_Schedule.pdf. Accessed May 25, 2015.
36. Pears R, 2002. Flowery by name: ferocious by nature. *Fish Fish Newsl* 1: 3.
37. Awira R, Friedman K, Sauni S, Kronen M, Pinca S, Chapman L, Magron F, 2008. *Kiribati Country Report: Profiles and Results from Survey Work at Abaiang, Abemama, Kuria and Kiritimati (May to November 2004)*. Noumea, New Caledonia: Secretariat of the Pacific Community, Coastal Fisheries Programme.
38. McGilvray F, Chan TTC, 2002. The trade in live reef food fish: A Hong Kong perspective. *Aquaculture Asia* 7: 21–26.
39. Laurent D, Yeeting B, Labrosse P, Gaudechoux JP, 2005. *Ciguatera: Field Reference Guide*. Noumea, New Caledonia: Secretariat of the Pacific Community and Institute of Research for Development.
40. Letourneur Y, Kulbicki M, Labrosse P, 1998. Length-weight relationship of fishes from coral reefs and lagoons of New Caledonia: an update. *Naga ICLARM Q* 21: 39–46.
41. Sadovy Y, 1998. Marketing and monitoring live reef fishes in Hong Kong, an update. *SPC Live Reef Fish Inform Bull* 4: 47–51.
42. Withers NW, 1982. Ciguatera fish poisoning. *Annu Rev Med* 33: 97–111.
43. Hashimoto Y, Yasamoto T, 1965. A note on ciguatera poisoning in Okinawa and the toxin of a grouper, *Epinephelus fuscoguttatus* Forskal. *Bull Jap Soc Sci Fish* 31: 452–458.
44. Shakeel H, Ahmed H, 1997. Exploitation of reef resources, grouper and other food fishes in the Maldives. *SPC Live Reef Fish Inform Bull* 2: 14–20.
45. European Food Safety Authority, 2010. Scientific opinion on marine biotoxins in shellfish – emerging toxins: ciguatoxin group. *EFSA J* 8: 1627.
46. Centre for Food Safety, 2012. *Food Safety Ordinance (Chapter 612)*. Available at: http://www.cfs.gov.hk/english/whatsnew/whatsnew_fstr/whatsnew_fstr_Food_Safety_Bill.html. Accessed May 25, 2015.