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Methylmercury and long-chain n-3 fatty acids of 88 fish species commonly consumed in Hong Kong

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Abstract

Background: Fish is considered by nutritionists as the main source of omega 3 (n-3) polyunsaturated fatty acids which is not available in common edible plant oils. However, methylmercury (MeHg) in fish is considered as the major contributor from food. Risk benefit analysis of MeHg and n-3 fatty acids became a hot topic in the past decade. Different risks and benefit analysis on the consumption of fish have been reported, but most of the analyses were based on the data extracted from different databases.

Results: This study provided the levels of n-3 fatty acids, MeHg, and total mercury (tHg) of different fish species commonly consumed in Hong Kong. Among the sampled 88 species of fresh/frozen whole fish, all samples were found to contain quantifiable amount of n-3 fatty acids, MeHg, and tHg. The levels of n-3 fatty acids (EPA plus DHA) in local or imported fish species are ranging from 0.31 to 20.6 mg per g while the highest level was found in Atlantic salmon. For MeHg, the highest content was found for alfonsino at the level of 0.827 μg per g.

Methods: A modified AOAC 990.08 was single laboratory validated and used for analysis n-3 fatty acids content of fish samples.

Conclusions: This paper presents the n-3 fatty acids and MeHg content in 88 fish species. These original results are consistent with overseas findings and are useful in risk/benefit assessment of fish consumption recommendations in general.

Keywords: Fish species; n-3 fatty acids; Methylmercury; Total mercury; EPA; DHA; Hong Kong

Background

For many years, fish has often been the focus of attention in both contaminants and nutritional studies. Nutritionists [1] consider seafood to be an important source of high-quality proteins, vitamin D, and essential fatty acids (EFAs). EFAs are similar to vitamins in terms of their importance to our health. Unlike vitamins, EFAs are macronutrients (i.e., necessary in g/day). A joint study released by the Food and Agriculture Organization and the World Health Organization [2] recommends that at least 6% to 10% of our daily calorie intake be in the form of EFAs.

Current dietary guidelines recommend a diet low in saturated fatty acids (SFAs), with a moderate amount of monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs), including the n-6 and n-3 families. The recommended ratio of n-6 to n-3 usually varies between 4:1 (or less) and 10:1. The human body cannot produce all n-3 fatty acids, but two of them, it needs. These two, linoleic acid and alpha-linolenic acid, are widely distributed in plant oils. Fish oils contain the longer-chain n-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), while other marine oils, such as from seal, contain significant amounts of docosapentaenoic acid (DPA). The n-3 fatty acids found in fish oils and marine oils can help to fulfill the requirement of EFAs.

The level of MeHg in fish is of particular concern worldwide because significant exposure to MeHg can cause adverse effect to the nervous system, especially the developing brain. In 2000, JECFA established a PTWI of 3.3 ug per kg bw per week for the general population

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but highlighted that the fetus and infant might be at a greater risk of toxic effects [3]. In 2003, this PTWI was reduced to 1.6 ug per kg bw per week following further risk assessment [4]. This value was considered to be sufficient to protect the developing fetus, which are the most sensitive to MeHg.

However, the health risk of chemicals/nutrients in fish is usually assessed separately. In recent years, the evolving science and debate concerning the risks and benefits of consuming fish have resulted in confusion as to how much fish should be consumed. National food safety agencies have recognized the need to provide useful, clear, and relevant information to populations that are concerned about making the healthiest choices when considering whether or not to eat fish [5,6].

Mahaffey [7] noted the interplay between fatty acids and MeHg and provided data on typical contents by species of fish or shellfish. Besides, she also commented that the choice of fish species by consumers is crucial to the balance between the risks and benefits of consuming fish. AFSSA [8] concluded the advantages of diversifying the consumed fish and seafood species in terms of proportions and provisioning origins in order to ensure a rational balance between benefits and risks compatible with nutritional and toxicological recommendations. Mozaffarian et al. [9] reported the benefits of fish intake exceed the potential risks based on both the strength of the evidence and the potential magnitudes of effect. For women of childbearing age, benefits of modest fish intake, excepting a few selected species, also outweigh risks. Zhang et al. [10] concluded that the changes in fish consumption related to MeHg advisories have a minor influence on the intake of EPA and DHA and on the percentage of women with EPA and DHA intake exceeding the guideline for Japanese women. Subsequently, US FDA [11] published a draft quantitative risk and benefit assessment report on the consumption of commercial fish and focused on fetal neurodevelopmental effects. Nevertheless, this simulation could aid the selection of fish species in order to ensure adequate intake of EPA and DHA while minimizing exposure to MeHg.

The 38th Session of the Codex Committee on Food Additives and Contaminants requested the Codex Alimentarius Commission to convene a Joint Food and Agriculture Organization of the United Nations (FAO)/ World Health Organization (WHO) Expert Consultation on the health risks associated with the presence of MeHg and dioxins in fish as well as the health benefits of fish consumption. FAO and WHO then convened a Joint Expert Consultation in Rome in January 2010 to assess the issues. The Expert Consultation concluded that fish is a major source of food and essential nutrients in some populations, and consumption of fish provides energy, protein, and a range of other important nutrients, including the long-chain n-3 polyunsaturated fatty acids [12]. Among the general adult population, the consumption of fish, particularly fatty fish, lowers the risk of mortality from coronary heart disease. There is an absence of probable or convincing evidence of risk of coronary heart disease associated with MeHg.

Most of the levels of MeHg (or tHg) and n-3 fatty acids used for the discussion were based on data extracted from different databases. However, levels of MeHg contamination vary widely. Among different species of tuna, there is a three-fold difference in mean levels of contamination between canned light tuna (0.128 ppm) and canned albacore tuna (0.350 ppm) or tuna that is sold fresh or frozen (0.391 ppm) [13]. MeHg contamination also varies greatly between individual fish and depends on its species, age (size), mercury levels in living environment, and food sources. Therefore, the evaluation between MeHg and omega-3 fatty acids based on data extracted from databases might not truly reflected the correlation but provided a general picture of the relationship.

Among the literatures, the reports that analyzed both the levels of MeHg and omega-3 fatty acids in different fish species are rare. The CALIPSO study conducted by AFSSA has analyzed both the levels of MeHg and n-3 fatty acids of 30 different fish but not down to fish species.

Hong Kong is a city well known for its high consumption of seafood. Recently, around 90 commonly consumed fish species have been collected and analyzed for their total and MeHg contents. The exposure of tHg and MeHg from food in Hong Kong has also been assessed [14]. Besides, the fatty acid profiles of these fishes were analyzed. As FAO/WHO [12] encouraged member countries to generate representative data on levels of n-3 fatty acids, mercury, and dioxins in fish species in the form consumed in their countries, this paper summarized and presented the findings of tHg, MeHg, and n-3 fatty acids (EPA and DHA) of these fish species.

Methods

Samples

Fish species commonly consumed in Hong Kong were randomly sampled during the sampling period of April to August of 2007 from various premises, including supermarkets and fresh provision shops, at different locations for marine fish or freshwater fish in whole fish form for identification:

- Local fish from wet markets and other fish-selling premises
- Imported fish for preparation by restaurant

Fish samples from the same batch were collected and sent to the Agriculture, Fisheries and Conservation

Department (AFCD) for species identification. The samples were gutted and separated into edible portion including skin and flesh, homogenized and stored at −20°C until they were analyzed. For each fish species, equal weight of the primary samples was mixed, ground, and remixed to obtain a single homogeneous composite sample before analysis. The composite fish samples were analyzed on composite basis for fatty acids (50 fatty acids in all). The number of fish species and the number of individual samples collected for each species were limited by resources available and availability of fish during the sampling period. Ideally, examination of more samples for each species would better reflect the mercury levels for each species.

Analytical determination of tHg, MeHg, and fatty acids

For tHg determination, all food samples were digested according to modified AOAC Official Method 990.08. In brief, the samples were digested by concentrated nitric acid at 95°C for 2 h. Then, H_2O_2 was added, and the mixture was kept at 95°C for another 1 h. After dilution, the quantification of tHg was performed by a flow injection mercury analyzer equipped with an amalgam preconcentration system (FIMS 100, Perkin-Elmer, Wellesley, MA, USA).

For MeHg, homogenized fish sample was extracted with 50% HCl by sonication for 3 h. After centrifugation, the extract was derivatized with sodium tetraphenylborate. The quantification of MeHg was performed by a gas chromatograph-mass selective detector, operating in the selective ion monitoring mode [15].

All fish samples were analyzed according to a slightly modified AOAC Official Method 996.06. In brief, the lipid of the samples was hydrolyzed by concentrated nitric acid. Pyrogallic acid was added to prevent oxidative degradation of fatty acids during acid hydrolysis while triundecanoin was added as internal standard. After hydrolysis, fatty acids extracted into diethyl ether were concentrated and then methylated to fatty acid methyl esters (FAMEs) with boron trifluroide as derivatizing agent. FAMEs yielded were quantitatively measured by using a gas chromatograph equipped with flame ionization detection system (6890: Agilent Technologies, Santa Clara, CA, USA). The separation was achieved with a SP-2560 (100 m × 0.25 mm × 0.28 μm) column. The oven was hold at 100°C for 4 min, then ramped to 240°C with rate of 3°C/min and held for another 20 min. The injector temperature was 225°C with split ratio of 150:1.

Results and discussion

Method

Though a number of capillary columns claimed that they are suitable for the separation of FAMEs, none of them could baseline separate each FAMEs. In order to obtain better separation or more theoretical plates, the carrier gas was changed to hydrogen instead of helium. Upon such minor modification of the method, almost every peak of FAMEs standard could be well resolved except the peaks of C18:1n−7 t, −9 t, and −12 t that cannot be completely resolved. Further, the separation between the GC peaks of C22:1n−9 t and C20:3n-3 became baseline separated (see Figure 1). In general, the limit of quantification can attain down to 0.004 mg per 100 g flesh weight.

tHg, MeHg, and fatty acid profile

Table 1 summarized the fish species, tHg, MeHg level, and concentration n-3 fatty acids (EPA and DHA) of commonly consumed fish in Hong Kong. Levels of other n-3 fatty acids were summarized in Table S1. The fishes containing the highest amount of fat are Japanese eel, Altanic salmon, and yellow croaker, with levels of more than 10 per 100 g, while those with the lowest content of fat are tonguefish and orange-striped emperor, with levels less than 300 mg per 100 g.

All of the samples were found to contain quantifiable amount of MUFAs and PUFAs. The levels of MUFAs and PUFAs in different fish species ranged from 27.2 to 9,730 to 67.9 to 4,140 mg per 100 g, respectively, while the highest MUFAs and PUFAs levels were found in Japanese eel and Atlantic salmon, respectively. Small amount of trans fatty acids was detected in most of the tested fish species except starspotted grouper, honeycomb grouper, Bombay duck, and white-edged lyretail while the highest level was found for grey mullet at 93.9 mg per 100 g.

For n-3 and n-6 PUFAs, the highest content was found for Atlantic salmon and grey mullet at the level of 2,900 and 1,980 mg per 100 g, respectively. Regarding EPA, DHA, and DPA, fatty acids that need to be intake from food, the total amount varied from 31.3 to 2,510 mg per 100 g. No matter whether the individual or sum of these n-3 fatty acids is concerned, the highest amount was found in Atlantic salmon. While Japanese eel, laced moray, grunt, yellow croaker, silver pomfret, false halibut, white trevally, purple amberjack, and yellowtail kingfish from region B were also found to contain more than 1,000 mg per 100 g of these n-3 fatty acids. Hence, the choice for fishes rich in these n-3 fatty acids is not limited.

Among DHA, EPA, and DPA in 88 fish species, DHA was found to be the highest. Further, DPA was not detected in six different fish species and does not seem to depend on the lipid content. For fish species with more than 1,000 mg of the sum of DPA, DHA, and EPA per 100 g, the content of these n-3 fatty acids is in the order of DHA > EPA > DPA, except for laced moray in which the level of DPA is higher than EPA. However, such order is not applicable for fish species with low n-3 fatty acids.

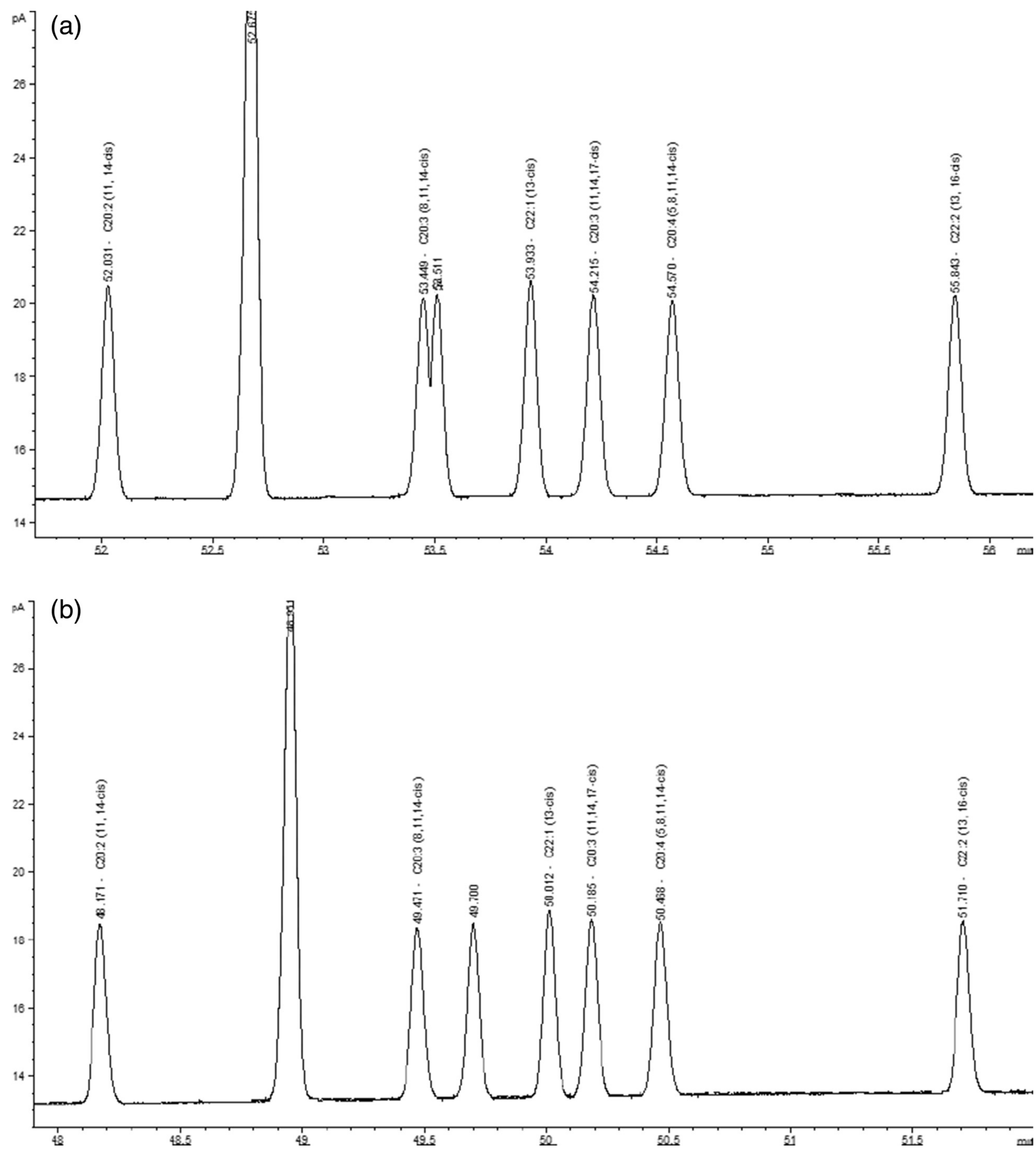

Figure 1 **Gas chromatograms of fatty acid standards with (a) helium and (b) hydrogen as carrier gas.**

Regional variations

For samples of fish that shipped from a specific country, it is not necessary true that the fish was caught or produced in that country. It was also noted that in the same *Seriola lalandi* species, significantly different fatty acid levels were found in samples coming from different regions. Although *S. lalandi* from region B (in South Pacific Ocean) was just about 10% shorter than that of region A (in North Pacific Ocean), the n-3 fatty acids content was three times more than that of region A. Figure 2 showed the ratios of n-3 fatty acid and MeHg of *S. lalandi* from regions A and B. Furthermore, the major fatty acids from regions A and B were found to be SFA and MUFA, respectively, i.e., significantly different from each other. The fatty acid profiles of

Table 1 Overview of test results of 88 fish samples collected in this study

Item	Fish species	Common name	Number of samples	tHg	MeHg	EPA	DHA	EPA + DHA
1	*Acanthopagrus latus*	Yellowfin seabream	4	0.041	0.034	1.28	3.34	4.62
2	*Acanthopagrus schlegeli*	Black porgy, blackhead seabream	1	0.136	0.116	0.21	0.74	0.94
3	*Anguilla japonica*	Japanese eel	5	0.071	0.060	2.99	7.51	10.5
4	*Ariomma indica*	Indian ariomma, Indian driftfish	3	0.010	0.005	0.32	1.77	2.09
5	*Aristichthys nobilis*	Bighead carp	3	0.036	0.029	0.33	0.52	0.85
6	*Beryx splendens*[a]	Splendid alfonsino	3	1.053	0.827	0.94	2.90	3.84
7	*Branchiostegus albus*	White horsehead	4	0.073	0.059	0.87	3.04	3.91
8	*Cephalopholis urodeta*	Darkfin hind	3	0.094	0.087	0.13	1.03	1.16
9	*Channa maculata*	Snakehead, blotched snakehead	3	0.048	0.037	0.59	2.78	3.37
10	*Choerodon schoenleinii*	Green wrasse, blackspot tuskfish	4	0.095	0.076	0.33	0.64	0.96
11	*Cirrhinus molitorella*	Mud carp	3	0.039	0.030	0.61	1.20	1.81
12	*Clarias fuscus*	Catfish, Hong Kong catfish	3	0.007	0.005	0.54	1.62	2.16
13	*Cololabis saira*[a]	Pacific saury	3	0.056	0.042	0.16	0.36	0.52
14	*Cromileptes altivelis*	Humpback grouper	3	0.101	0.078	0.08	0.64	0.73
15	*Ctenopharyngodon idellus*	Grass carp	3	0.008	0.003	0.08	0.49	0.57
16	*Cynoglossus arel*	Largescale tonguesole, tonguefish	3	0.075	0.057	0.13	0.39	0.52
17	*Cynoglossus bilineatus*	Fourlined tonguesole	3	0.039	0.028	0.13	0.55	0.68
18	*Dentex tumifrons*	Golden tail, yellowback seabream	4	0.281	0.253	0.90	4.21	5.11
19	*Eleutheronema tetradactylum*	Fourfinger threadfin, blind tasselfish	3	0.065	0.048	3.59	4.83	8.42
20	*Epinephelus areolatus*	Areolate grouper, green-spotted rock cod	3	0.066	0.047	1.52	5.22	6.74
21	*Epinephelus awoara*	Yellow grouper, banded grouper	3	0.118	0.087	0.35	1.16	1.51
22	*Epinephelus bleekeri*	Duskytail grouper	3	0.080	0.067	0.63	2.34	2.97
23	*Epinephelus coioides*	Green grouper, orange-spotted grouper, estuary grouper	3	0.057	0.047	0.34	1.33	1.67
24	*Epinephelus fasciatomaculosus*	Rock grouper, banded reef-cod	3	0.086	0.063	0.66	1.20	1.86
25	*Epinephelus hexagonatus*	Starspotted grouper	2	0.065	0.056	0.05	0.59	0.64
26	*Epinephelus lanceolatus*	Giant grouper	4	0.051	0.037	2.61	4.58	7.19
27	*Epinephelus merra*	Honeycomb grouper	1	0.033	0.030	0.07	0.53	0.61
28	*Epinephelus quoyanus*	Longfin grouper	1	0.068	0.060	0.64	1.89	2.53
29	*Epinephelus trimaculatus*	Threespot grouper	1	0.076	0.055	0.17	0.76	0.92
30	*Gymnothorax favagineus*	Laced moray	1	0.166	0.123	2.29	7.13	9.42
31	*Gymnothorax reevesii*	Reeve's moray	3	0.067	0.055	1.05	4.05	5.10
32	*Hapalogenys nitens*	Skewband grunt, grunt	3	0.118	0.078	3.64	11.90	15.5
33	*Harpadon nehereus*	Bombay duck	3	0.017	0.013	0.14	0.43	0.57
34	*Katsuwonus pelamis*[a]	Skipjack tuna	3	0.143	0.128	0.12	0.97	1.09
35	*Larimichthys croceus*	Yellow croaker, croceine croaker, large yellow croaker	3	0.044	0.036	3.41	9.52	12.9
36	*Lateolabrax japonicus*	Japanese seaperch, common sea bass, Japanese seabass	5	0.038	0.028	0.73	1.59	2.32
37	*Lates calcarifer*	Barramundi	6	0.091	0.077	0.24	0.71	0.95
38	*Lethrinus obsoletus*	Orange-striped emperor	2	0.050	0.037	0.11	0.44	0.55
39	*Lutjanus argentimaculatus*	Mangrove red snapper	5	0.060	0.046	0.49	1.16	1.65
40	*Lutjanus malabaricus*	Red snapper, Malabar blood snapper	3	0.106	0.078	0.29	1.02	1.31
41	*Lutjanus russelli*	Russell's snapper, fingermark bream	3	0.112	0.087	0.12	0.94	1.07

Table 1 Overview of test results of 88 fish samples collected in this study *(Continued)*

42	*Lutjanus stellatus*	Star snapper	3	0.161	0.105	0.53	1.53	2.06
43	*Megalobrama terminalis*	Black amur bream	1	0.007	0.006	0.10	0.21	0.31
44	*Micropterus salmoides*	Largemouth bass, largemouth black bass	3	0.069	0.050	1.12	4.25	5.37
45	*Mugil cephalus*	Grey mullet, flathead grey mullet	3	0.014	0.009	1.00	1.35	2.35
46	*Mulloidichthys flavolineatus*	Yellowstripe goatfish	1	0.042	0.030	0.22	0.81	1.03
47	*Nemipterus japonicus*	Japanese golden thread, Japanese threadfin bream	4	0.036	0.031	0.89	1.73	2.62
48	*Nemipterus virgatus*	Golden threadfin bream, golden thread	3	0.054	0.041	1.16	3.63	4.79
49	*Oreochromis niloticus niloticus*	Tilapia, Nile tilapia	4	0.017	0.013	0.06	0.65	0.70
50	*Pagrus major*	Red pargo, Japanese seabream, Red seabream	3	0.051	0.039	1.70	6.41	8.11
51	*Pampus argenteus*	Silver pomfret, butterfish, pomfret	5	0.017	0.011	2.42	7.70	10.1
52	*Pampus nozawae*	Swallow tail pomfret	3	0.024	0.015	0.97	4.02	4.99
53	*Paralichthys olivaceus*[a]	False halibut, bastard halibut	3	0.048	0.035	4.26	7.90	12.2
54	*Parupeneus barberinus*	Dash-and-dot goatfish	1	0.15	0.136	0.14	0.43	0.57
55	*Parupeneus indicus*	Indian goatfish	2	0.188	0.166	0.87	1.19	2.06
56	*Pennahia argentata*	White croaker, white chinese croaker, silver croaker	5	0.079	0.062	0.19	1.86	2.05
57	*Platycephalus indicus*	Flathead, bartail flathead	4	0.108	0.081	0.66	1.62	2.28
58	*Platycephalus spp*	Flathead	1	0.051	0.041	0.59	2.05	2.64
59	*Plectorhinchus cinctus*	Cresent sweetlips, grunt	3	0.064	0.050	0.10	1.01	1.11
60	*Plectropomus areolatus*	Squaretail coralgrouper	2	0.091	0.068	0.13	1.04	1.17
61	*Plectropomus leopardus*	Leopard coralgrouper	4	0.052	0.042	0.14	1.46	1.60
62	*Pomadasys kaakan*	Javelin grunter	4	0.090	0.078	0.20	1.09	1.29
63	*Priacanthus tayenus*	Purple-spotted bigeye, big-eye perch	4	0.044	0.033	0.50	2.00	2.50
64	*Priacanthus macracanthus*	Red bigeye, bulls-eye perch	2	0.019	0.012	0.28	1.82	2.10
65	*Psenopsis anomala*	Butter fish, Pacific rudderfish	4	0.013	0.010	0.54	1.45	1.99
66	*Pseudocaranx dentex*[a]	White trevally	3	0.101	0.084	5.13	8.70	13.8
67	*Rachycentron canadum*	Black bonito, cobia	1	0.101	0.100	0.15	0.43	0.57
68	*Salmo Salar*[a]	Atlantic salmon	3	0.034	0.025	8.40	12.20	20.6
69	*Sarda orientalis*[a]	Striped bonito	3	0.101	0.076	0.57	1.62	2.19
70	*Sardinops sagax*[a]	South American pilchard	3	0.031	0.026	0.54	2.10	2.64
71	*Saurida elongata*	Slender lizardfish	2	0.020	0.016	0.63	2.71	3.34
72	*Saurida tumbil*	Greater lizardfish	1	0.024	0.018	0.62	2.79	3.41
73	*Scatophagus argus*	Spotted scat, butter fish, spade fish	3	0.034	0.028	0.82	3.00	3.82
74	*Scomber japonicus*[a]	Chub mackerel	3	0.213	0.152	0.19	1.02	1.21
75	*Scomberomorus commerson*	Narrow-barred Spanish mackerel, albacore, banded tuna	1	0.083	0.059	0.45	2.21	2.66
76	*Scomberomorus guttatus*	Indo-pacific king mackerel	5	0.087	0.069	0.38	2.21	2.59
77	*Sebastiscus marmoratus*	Rockfish	3	0.033	0.025	0.82	1.68	2.50
78	*Seriola dumerili*[a]	Purple amberjack, greater amberjack	3	0.113	0.089	4.31	8.33	12.6
79A	*Seriola lalandi*[a] (Region A)	Yellowtail kingfish, Yellowtail amberjack	3	0.219	0.192	0.65	2.47	3.12
79B	*Seriola lalandi*[a] (Region B)	Yellowtail kingfish, Yellowtail amberjack	3	0.031	0.023	6.08	6.70	12.8
80	*Siganus canaliculatus*	Rabbitfish, pearl-spotted spinefoot, white-spotted spinefoot	3	0.014	0.009	0.70	5.33	6.03
81	*Sillago japonica*	Japanese sillago	3	0.133	0.117	0.41	1.13	1.54
82	*Siniperca chuatsi*	Freshwater grouper, Mandarin fish	3	0.091	0.077	0.62	1.28	1.90
83	*Sphyraena flavicauda*[a]	Yellowtail barracuda, barracudas	3	0.295	0.216	0.40	0.91	1.30

Table 1 Overview of test results of 88 fish samples collected in this study *(Continued)*

84	*Trachinotus blochii*	Snubnose pompano	3	0.056	0.048	0.20	1.37	1.57
85	*Trachurus japonicus*[a]	Japanese jack mackerel, Atlantic horse mackerel	3	0.064	0.042	0.24	0.82	1.06
86	*Trichiurus lepturus*	Largehead hairtail, hairtail	5	0.091	0.069	0.65	2.83	3.48
87	*Trichiurus nanhaiensis*	Largehead hairtail, South China Sea hairtail	1	0.056	0.042	0.16	1.03	1.19
88	*Variola albimarginata*	White-edged lyretail	3	0.102	0.073	0.06	0.73	0.79

Note: Concentration of tHg and MeHg was in ug/g while n-3 fatty acids were in mg/g respectively.
[a]Denote imported fish.

these two regions were significantly different; hence, it is plausible that variation in living environments is an important factor in determining the fatty acid profile and content of MeHg in fish.

Relationship between MeHg and n-3 fatty acids

Figure 3 plotted the n-3 fatty acids and MeHg contents of 88 fish species. Besides alfonsino that had high MeHg and low n-3 fatty acids, other tested fish species were found to have relatively low MeHg content. This finding suggested that pregnant women, women planning pregnancy, and young children when selecting fish species in their diet should avoid eating predatory fish, alfonsino. In general, the plot is comparable to that reported by Mahaffey et al. (2008) and FAO/WHO study. It should be noted that only those fish species where the whole fish was available in the market were sampled.

Some imported fish that contained high levels of mercury were not available as whole fish and were therefore not included in the sampling and analyses in this study. Predator fish that were not sampled included swordfish, shark, marlin, tilefish, orange roughy, and other species of tuna (bluefin, bigeye, albacore, and yellowfin). Generally, predator fish were located in the region of low n-3 fatty acid and high level of MeHg in the chart plotting the levels of MeHg and n-3 fatty acids (EPA and DHA). However, both Zhang et al. [10] and FAO/WHO studies reported that Pacific bluefin tuna got high n-3 fatty acids and MeHg. In this study, the skipjack tuna sampled was found to have low n-3 fatty acids and MeHg.

Regarding the relative contents of MeHg of tHg in different fish species, i.e., the ratios of MeHg to tHg were in the range of 0.46 to 0.99 and in good agreement with the literature [16-19]. Therefore, the relationship between tHg and n-3 fatty acids is similar to that of MeHg and n-3 fatty acids.

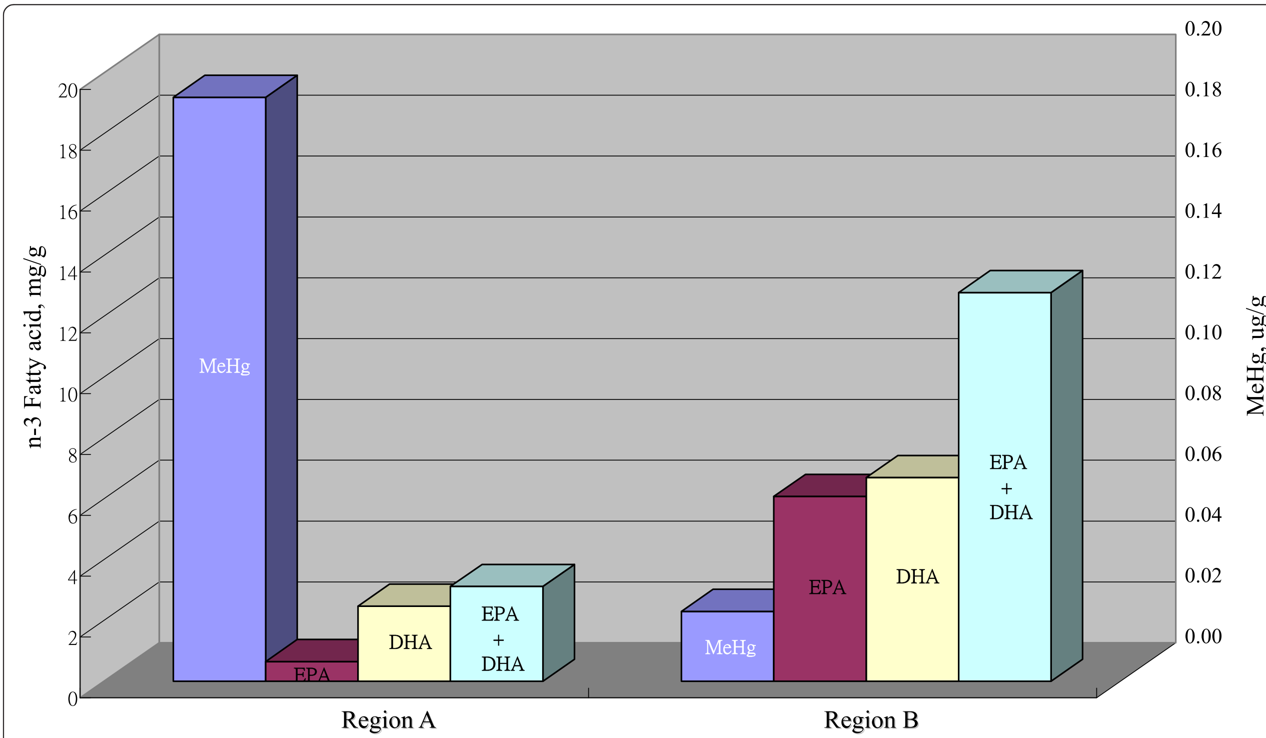

Figure 2 n-3 Fatty acids (mg/g) and MeHg (ug/g) concentration of *Seriola lalandi* in different regions.

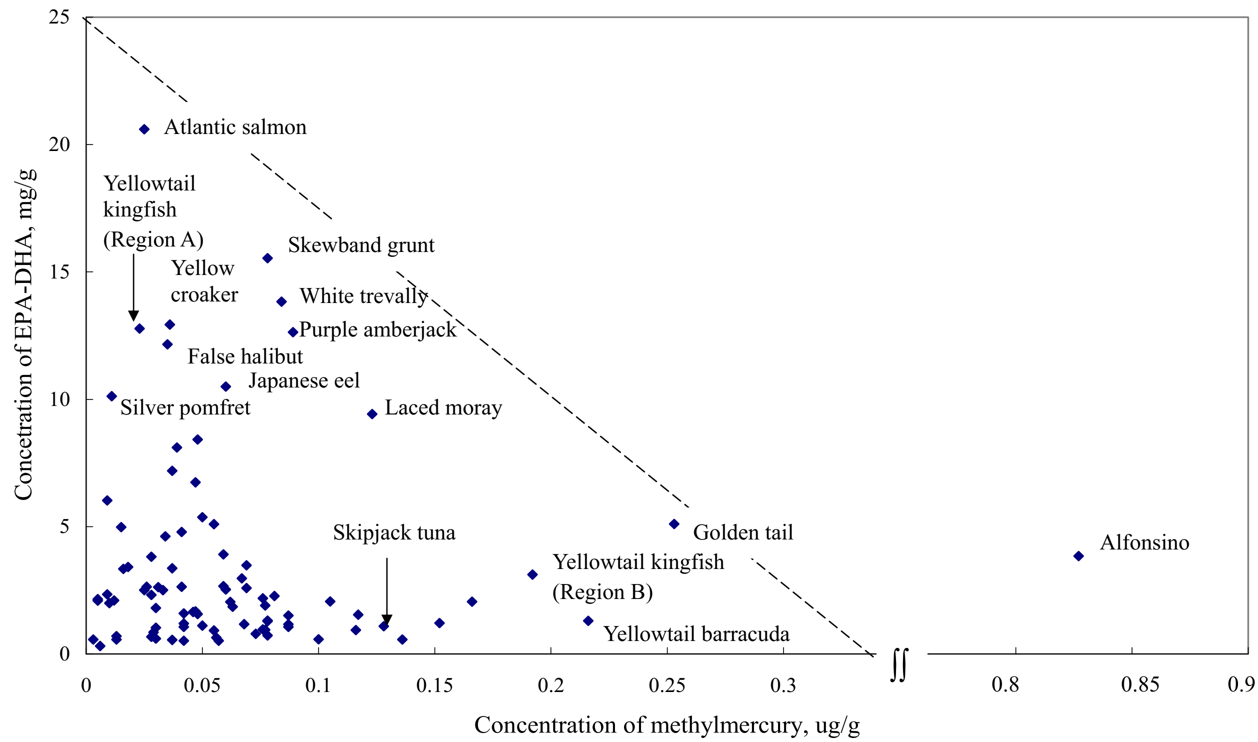

Figure 3 Cross-plot of omega-3 fatty acids (EPA + DHA) and methylmercury content of 88 fish species.

For each of the 88 fish species, the contents of MeHg and n-3 fatty acids (EPA plus DHA) were classified according to its levels in Table 2. When compared to the FAO/WHO study, the n-3 fatty acids of fish species are, in general, lower than that found in other countries. One of the possible reasons is that quite a number of different fish species available in Hong Kong is farmed, which included grouper, eel, snapper, etc. Therefore, the feed used would affect the level of n-3 fatty acids. For those wild fish, such as skipjack tuna and alfonsino, the living region is an important factor in determining the contents of MeHg and n-3 fatty acids. With reference to the present finding, most of the fish species, greater than 80% have mean MeHg levels of lower than 0.1 ug/g. Out of the 88 fish species, 25 different fish species could provide n-3 fatty acids greater than 3 mg/g. Further, n-3 fatty acids of 11 and 2 of these 25 fish species were found to greater than 8 and 15 mg/g on flesh weight, respectively.

In summary, the observed difference between this study and other similar studies might due to the fact that other datasets usually pooled data from different databases. Furthermore, the living environment is an important determinant of both n-3 fatty acids and MeHg levels. As

Table 2 Classification of the content of EPA plus DHA by methylmercury content in 88 fish species

Methylmercury	MEPA + DHA			
	$x \leq 3$ mg/g	$3 < x \leq 8$ mg/g	$8 < x \leq 15$ mg/g	$x > 15$ mg/g
$x \leq 0.1$ μg/g	Other fish species included in the study	Yellowfin seabream, white horsehead, snakehead, areolate grouper, giant grouper, Reeve's moray, largemouth bass, golden threadfin bream, swallow tail pomfret, slender lizardfish, greater lizardfish, spotted scat, rabbitfish, largehead hairtail	Japanese eel, fourfinger threadfin, yellow croaker, red pargo, silver pomfret, false halibut, white trevally, purple amberjack, yellowtail kingfish	Atlantic salmon, skewband grunt
$0.1 < x \leq 0.5$ μg/g	Black porgy, skipjack tuna, star snapper, dash-and-dot goatfish, Indian goatfish, chub mackerel, Japanese sillago, yellowtail barracuda	Golden tail, yellowtail kingfish	Laced moray	
$x > 0.5$ μg/g		Alfonsino		

suggested by FAO/WHO, local data with both the levels of MeHg and n-3 fatty acids should be obtained from different fish species to obtain a better picture.

Conclusions

This study provides both the n-3 fatty acid (EPA plus DHA) and MeHg levels of the most common fish species marketed in Hong Kong. Of the fish examined, 25 fish species containing MeHg of less than 0.1 μg/g and n-3 fatty acids greater than 3 mg/g were considered suitable as source of n-3 fatty acids. Eleven of these fish species were also found to contain high levels of n-3 fatty acids in the range of greater than 8 mg/g on flesh weight. The data of this study provide useful information to improve the existing databases on MeHg in fish in Hong Kong and nearby region.

Additional file

Additional file 1: Table S1. Overview of other n-3 fatty acids (mg/g) results of fish samples collected in this study.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

SKT has performed all the experimental and analytical work. SWCC guided the research and drafted the manuscript. YX and YYH provided comments and modified the manuscript. All authors read and approved the final manuscript.

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