Balancing the Risks and the Benefits of Local Fish Consumption in Bermuda

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Januray 24th, 2008

Introduction

Fish is one of the last remaining "wild foods" in the diets of Bermuda residents and represents not only a rich source of several unique dietary nutrients but also forms an important part of Bermuda's cultural identity as an island nation. Highlighting the benefits and minimizing the risks from seafood consumption is an important part of maintaining this resource's important nutritional and economic contribution to Bermuda's residents.

Fish consumption today is widely recognised as highly beneficial since it constitutes a good source of several essential nutrients, such as selenium and polyunsaturated fatty acids (n-3 PUFA). Several health organisations recommend eating fish twice a week for the general population (Harris 2004; Kris-Etherton et al. 2002). In fact, fish consumption is recognised as beneficial for brain development (Uauy et al. 2001) in the foetus and newborn and has been demonstrated to be protective against cardiovascular diseases (He et al. 2004; Wang et al. 2006), mental disorders (Logan 2003; Sinclair et al. 2007) and various inflammatory conditions such as bowel disease, asthma, and arthritis (Ruxton et al. 2004). Despite the fact that n-3 fatty acids can be found in other foods, fish remains the best and richest source of these nutrients and hence is an important part of a healthy diet. Coastal populations have a generally high intake of long chain polyunsaturated fatty acids (PUFAs), the most important compounds being eicosapentanoic acid (EPA) and docosahexanoic acid (DHA). During pregnancy, fish consumption provides DHA to the mother and the foetus which is critical in brain and retina development (Hibbeln et al. 2007; Lauritzen et al. 2004). In addition, fish and seafood are a very good natural source of selenium (Se) (Leung et al. 2007; Svensson et al. 1992). Concentrations of this element in foods depend on the local geological composition. It has been proposed that selenium may exert an antagonistic effect on mercury toxicity (WHO 1990) and have a mediating effect on certain cancers, specifically prostate cancer.

On the other hand, fish may also carry a certain load of mercury, most of which occurs in the form of methylmercury (MeHg) (over 90%). This phenomenon occurs because fish feed on aquatic organisms that contain MeHg originating from biomethylation of inorganic mercury by micro organisms. Mercury has always been present in all the worlds' oceans as a result of river run off, undersea volcanoes, air deposition etc and has always built up in fish at the top of the food chain. However, in the last century the industrialisation of many countries has resulted in a net increase in the load of mercury in the environment, which consequently is manifest in the world's fish and in those people who consume them. This is not a local Bermuda problem but a global one. Coastal people living in some of the most remote places on earth are in fact finding that their fish are as contaminated as fish in industrialised coastal areas.

The amount of MeHg in fish usually correlates with several factors including the weight and age of the fish, its trophic level and the species.

Numerous studies have reported that MeHg present in predator fishes represents a potential health threat for the developing foetus. As this seafood borne contaminant affects the development of the cerebral architecture by perturbing neural cell division and migration, the developing nervous system is recognized as the main target (Castoldi et al. 2001; Counter and Buchanan 2004). Several prospective cohort studies have reported effects of prenatal exposure to MeHg on different domains of cognition (attention, memory, visuo-spatial performances and language) and gross and fine motor development, some of which persist well beyond the first years of life

(Debes et al. 2006; Grandjean et al. 1997; Steuerwald et al. 2000). In contrast, a large epidemiological study from the Seychelle Islands did not find any effects on infant neurodevelopment from chronic MeHg *in utero* exposure (Davidson et al. 2006; Myers et al. 2003). Several explanations have been proposed to explain this discrepancy such as; chronic versus episotic exposure, age at neurobehavioral assessment, differential confounders adjustment, etc. (National Research Council 2000).

In 2004, as part of the Atlantis Mission, we conducted a study entitled “Prenatal exposure of the Bermudian Population to Environmental Contaminants” which aimed to provide baseline data on prenatal exposure to a number of environmental contaminants, including Hg. Mean Hg concentration measured in umbilical cord blood from 42 healthy newborns was higher than expected, with a mean concentration of 41.3 nmol/L, ranging from 5 nmol/L to 160 nmol/L. (Dewailly and Pereg 2004) eight times the US average measured among women of childbearing age in 2000 (Mahaffey et al. 2004). Furthermore, it was estimated that 85% of total mercury measured was in the form of MeHg, pointing toward seafood as the main source of Hg exposure during pregnancy in Bermuda. In contrast Persistent Organic Pollutants (POPs) such as PCBs and chlorinated pesticides along with lead were also measured in cord blood but concentrations were very low (Dewailly and Pereg 2004). For that reason, only Hg was considered of public health concern.

The globalisation of contaminants and the strong media attention regarding the presence of these contaminants in fish in all the world oceans has made some consumers wary of fish consumption. This has been counterbalanced by western scientific discoveries of the last 20 years highlighting the unique health benefits to be gained from the consumption of fish. The educated consumer is today extremely sensitive in their consumption choice.

Given the fact that wild fish consumption is an important part of the lifestyle of many Bermuda residents and because this habit presents not only health benefits but also risks for pregnant women and their unborn children, Atlantis researchers and the Ministry of the Environment and the Ministry of Health undertook the task of substantiating the mercury, selenium and fatty acid profiles of fish in Bermuda. Such an assessment is necessary in order to provide a baseline for guidelines regarding the number of meals and the type of fish to be preferentially consumed in order to maintain the benefits associated with a fish-based diet while avoiding excessive exposure to MeHg, particularly during pregnancy.

Methods

Fish samples were collected in fall 2003 and summer 2006 from species generally caught at the top of the food chain (e.g., predatory reef fish, pelagic fish), and those that people might commonly consume. Fish were mostly caught by fishermen and given to the researchers, who sampled them on board the boat or at the lab. Some samples of local fresh fish were sampled at restaurants or bought at the store. A total of 307 fish were collected from 43 fish species and 351 samples were analyzed (305 flesh samples, 44 liver samples, 1 roe and 1 fat sample). Fish samples were packaged in plastic bags and stored at -20°C until laboratory analyses.

Laboratory analyses

Fish fillets were analysed for their mercury, selenium and fatty acid concentrations, whereas livers were analysed for their mercury and selenium contents only. Determination of mercury concentrations was performed in the Atlantis mobile laboratory and at the reference laboratory of the Québec Toxicology Center (INSPQ) by cold vapour atomic absorption mass spectrometry. Samples were digested in nitric acid in pressurised vials. Digests were analysed by cold vapour atomic absorption mass spectrometry in a Pharmacia mercury monitor, model 100. In this instrument, samples are vaporized through a cell that is crossed by a light beam and mercury concentration is calculated by comparing the absorbance at 254 nm with that obtained with a Hg standard curve. Results are expressed on a wet weight basis and the limit of detection using this method is 0,05 µg/g wet weight.

Selenium concentrations of local Bermuda fish were determined in flesh and liver samples at the INSPQ by inductively coupled plasma mass spectrometry (ICP-MS). Samples were diluted in ammonium hydroxide and elements were brought to their elementary form by passing through argon plasma before being identified by mass spectrometry. All samples were analysed on a Perkin Elmer Sciex Elan 6000 ICP-MS (DRC II for Hg) instrument. Detection limits for selenium were 0.01 µg/g.

The fatty acid compositions of fish fillets were measured at CRML (CHUQ) after total lipid extraction with chloroform/methanol mixture, phospholipid separation by thin layer chromatography and methylation of fatty acids), followed by capillary gas-liquid chromatography using a DB-23 column (39m x 0.25 mm ID x 0.25 um thickness) or a umn column (for trans fatty acids, 100m x 0.25 mm ID x 0.20 um thickness)in a HP-Packard GC chromatograph. This standard method is currently used at the Québec Lipid Research Centre. In our report we present the % of total n-3 PUFA as well as the total n-3 PUFA concentrations in milligrams per 220 gm. of flesh. Analyses of PUFA content were replicated for 16 fish of different species in order to assess the potential variability between essays. Percentages of variation in the % of total n-3 PUFA ranged between 0,4% to 13% whereas those for total n-3 PUFA (in mg per 220gm.) varied from less than 1% to 207%. The largest variation in total PUFA was found in a sample of Dusky shark. Variations in n-3 PUFA measurements may be attributable to the presence of residual pieces of skin and bones in the analysed samples.

Statistical analysis

For computational purposes, samples with undetected levels of mercury or selenium were attributed a value equal to half the detection limit, which was 0,025 μg/g and 0,005 μg/g respectively. Arithmetic means, standard deviations and range of mercury, selenium and fatty acid concentrations in flesh and/or liver were computed for species with more than one sample available. n-3 PUFA concentrations in mg were reported for a portion of 220 grams of fish. Correlations between fish mercury content and fish weight were carried out. For these analyses, data were available only for some of the samples and were therefore carried-out by species. Correlation analyses were carried-out using Pearson's correlation coefficients. For easier reading, *p* values are not shown.

Results

1. Mercury

Table 1 shows the mercury concentrations found in all fish flesh samples analysed (wet weight). These mean mercury concentrations can be compared to action limits determined by various international agencies (e.g., 0.5-1 µg/g) for importation of commercial fish. All samples showing a concentration above the 0.5 µg/g limit are indicated in bold. Swordfish and Blue marlin are the two species with the highest mercury content, followed by Bar jack/Green jack, Blue runner and Black grouper. For some species, the mean mercury concentration is below that threshold, but the range shows that some individuals may have values that are above. This is particularly the case for Wahoo and Yellowfin tuna. The lowest mean concentrations of mercury were found in Flying fish, Barber and Bermuda Chub.

Table 1: Mercury concentrations (µg/g) in the flesh of local fish and crustacean species

COMMON NAME	SCIENTIFIC NAME	N	MEAN ± ST. DEV	RANGE
Amberjack	Seriola dumerili	8	0.55 ± 0.46	0.20 – 1.55
Anchovy	Sardinella anchovia	1	0.07	
Bar jack/green jack	Caranx ruber	1	1.0	
Barber (creole fish)	Paranthias furcifer	12	0.035 ± 0.028	0.025 – 0.12
Barracuda	Sphyraena barracuda	7	0.73 ± 0.38	0.18 – 1.40
Bermuda chub	Kyphosus sectactatrix	15	0.038 ± 0.039	0.025 – 0.17
Bermuda Dolphinfish	Coryphaena hipparus	1	0.05	
Bermuda mackerel	Euthynnus alletteratus	15	0.68 ± 0.69	0.17 – 2.30
Bermuda spiny lobster	Panulirus argus	4	0.21 ± 0.08	0.15 – 0.30
Black grouper	Mycteroperca bonaci	8	0.87 ± 0.46	0.35 – 1.55
Blackfin Tuna	Thunnus atlanticus	2	0.20 ± 0.00	0.20 – 0.20
Blue marlin	Makaira nigricans	3	3.10 ± 0.17	3.00 – 3.30
Blue runner	Caranx crysos	10	0.98 ± 0.33	0.39 – 1.30
Blue-striped grunt	Haemulon sciurus	14	0.33 ± 0.09	0.20 – 0.51
Bone fish	Albula vulpes	1	0.50	
Bermuda Bonita (Almaco jack)	Seriola rivoliana	17	0.170 ± 0.139	0.025 – 0.53
Caesar grunt	Haemulon carbonarum	1	0.09	
Coney	Cephalopholis fulva	29	0.21 ± 0.10	0.10 – 0.52
Deep water red snapper	Etelis oculatus	1	0.52	
Flounder sp.	Bothus sp.	1	0.06	
Flying fish	Cypselurus heterurus	6	0.035 ± 0.016	0.025 – 0.057
Frys	Anchoa choerostoma	2	0.12 ± 0.01	0.05 – 0.19
Grasby	Epinephelus cruentatus	1	0.16	
Gray snapper	Lutjanus griseus	13	0.28 ± 0.17	0.09 – 0.68
Gummy shark (dogfish)	Mustelus antarcticus	1	1.4	
Gwelly	Pseudocaranx dentex	1	0.37	
Hogfish	Lachnolaimus maximus	8	0.067 ± 0.044	0.025 – 0.15
Hybrid coney-barber	Cephalopholis fulva/Paranthais furcifer	1	0.12	

COMMON NAME	SCIENTIFIC NAME	N	MEAN ± ST. DEV	RANGE
Longfin jack/bar jack	Caranx ruber	1	0.48	
Ocean robin	Decapterus macarellus	17	0.23 ± 0.09	0.07 – 0.35
Rainbow runner	Elagatis bipinnulata	2	0.16 ± 0.06	0.11 – 0.20
Red hind	Epinephelus guttatus	29	0.26 ± 0.08	0.14 – 0.41
Red snapper	Lutjanus sp	2	0.10 ± 0.01	0.09 – 0.10
Sixgill shark	Hexanchus griseus	1	0.92	
Swordfish	Xiphias gladius	1	3.31	
Tapioca fish	Ruvettus nuvettus	1	0.15	
Tuna	Thunnus sp.	5	0.35 ± 0.21	0.21 – 0.70
Turbot	Balistes capriscus	8	0.072 ± 0.024	0.025 – 0.10
Wahoo	Acanthocybium solandri	14	0.34 ± 0.27	0.06 – 1.00
White water (lane)snapper	Lutjanus synagris	16	0.43 ± 0.12	0.17 – 0.60
Yellowfin tuna	Thunnus albacares	17	0.37 ± 0.18	0.18 – 1.10
Yellowtail snapper	Ocyurus chrysurus	6	0.35 ± 0.23	0.05 – 0.65

Mercury concentrations in the liver, fat and roe of some species are found in Table 2. Mean mercury concentrations above the 0.5 µg/g limit are also indicated in bold. Gummy and Sixgill sharks are the two species with the highest mercury concentrations in liver, followed by Gray snapper and Coney. Mercury concentrations in the flesh of fish were highly correlated with mercury liver levels (r = 0.60). The concentration of mercury in liver was always higher than in flesh except for Black grouper, Bonita and Dusky shark.

Table 2: Mercury concentrations in the liver fat and roe of some local fish species

COMMON NAME	SCIENTIFIC NAME	TISSUE	N	MEAN ± ST. DEV	RANGE
Barber (Creole fish)	Paranthias furcifer	Liver	7	0.21 ± 0.08	0.09 – 0.33
Bermuda chub	Kyphosus sectator	Liver	8	0.21 ± 0.08	0.07 – 0.32
Black grouper	Mycteroperca bonaci	Liver	1	0.025	
Bonita (Almaco jack)	Seriola rivoliana	Liver	3	0.04 ± 0.03	0.03 – 0.07
Coney	Cephalopholis fulva	Liver	13	1.07 ± 0.31	0.66 – 1.60
Coney	Cephalopholis fulva	Fat	1	0.25	
Galapagos shark	Carcharhinus galapagensis	Liver	1	0.65	
Gray snapper	Lutjanus griseus	Liver	2	1.14 ± 1.22	0.28 – 2.00
Gummy shark (dogfish)	Mustelus antarcticus	Liver	1	2.70	
Gwelly	Pseudocaranx dentex	Liver	1	0.98	
Hogfish	Lachnolaimus maximus	Liver	2	0.23 ± 0.11	0.15 – 0.30
Hogfish	Lachnolaimus maximus	Roe	1	0.025	
Red hind	Epinephelus guttatus	Liver	1	0.63	
Sixgill shark	Hexanchus griseus	Liver	1	19.10	

Figure 1: Mercury concentrations in fish and recommendations for pregnant women

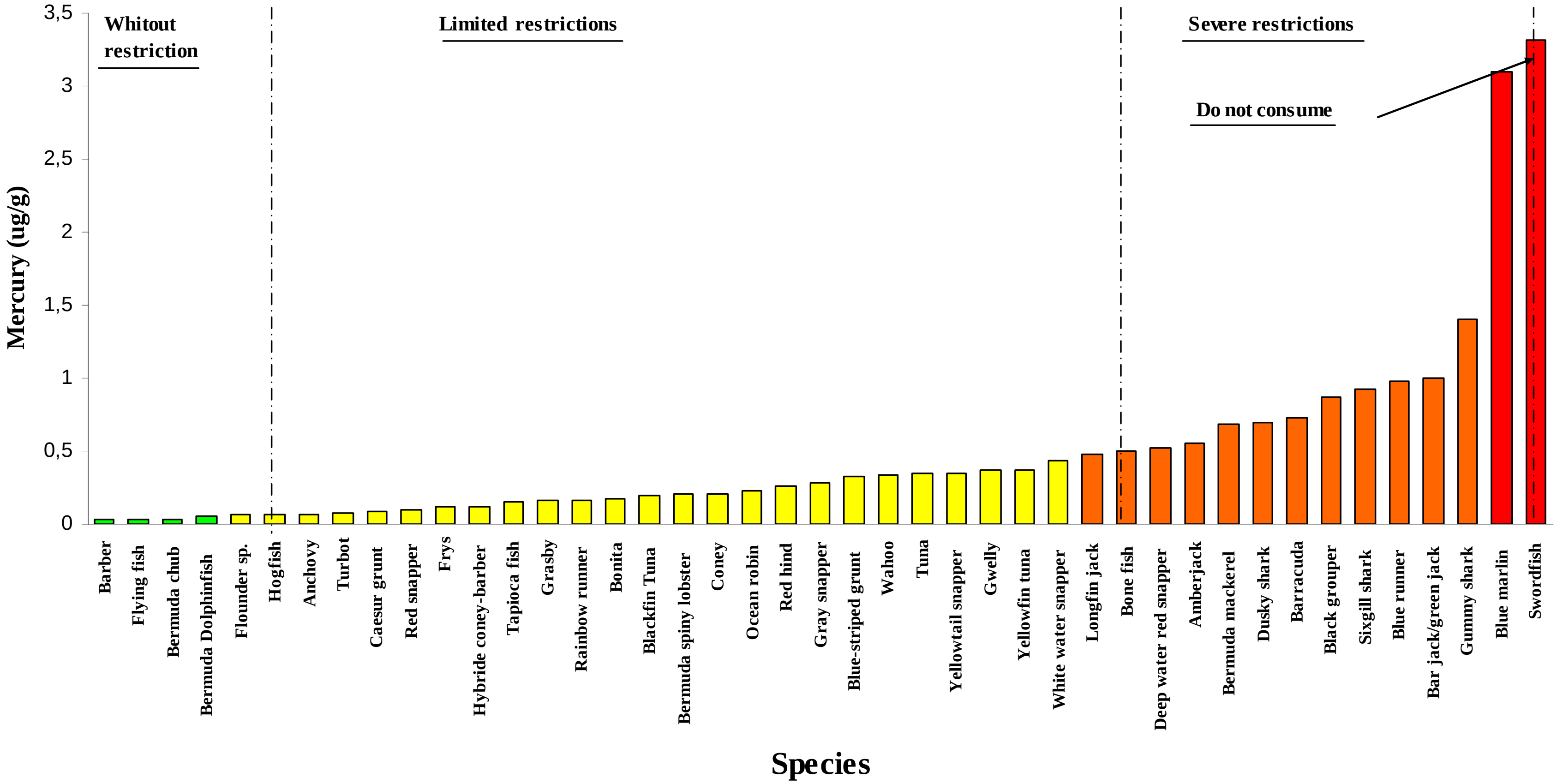


Figure 1 tabulates local fish species according to the increasing concentrations of Hg in their flesh. In order to help protect the developing foetus against the effects of MeHg, the number of fish portions (220 gm) that can be consumed per week by a pregnant women have been calculated. These calculations are based on the provisional tolerable weekly intake (PTWI) for MeHg of 1.6 ug/kg bodyweight recommended by the FAO/WHO (FAO/WHO Expert Committee on Food Additives 2006), **these recommendations for fish consumption assume that no others species of fish are consumed during the same period.** Based on the mercury concentrations measured in the flesh of local fish species we have come up with four human consumption categories for fish, each category representing a suggested consumption frequency for pregnant women in order to help ensure that the PTWI will not be reached:

Without restriction: Species that can be consumed every day.

Limited or little restriction: Species that can be consumed between once per day and once per week.

Strong or Severe restriction: Species that can be consumed once per week to once per month.

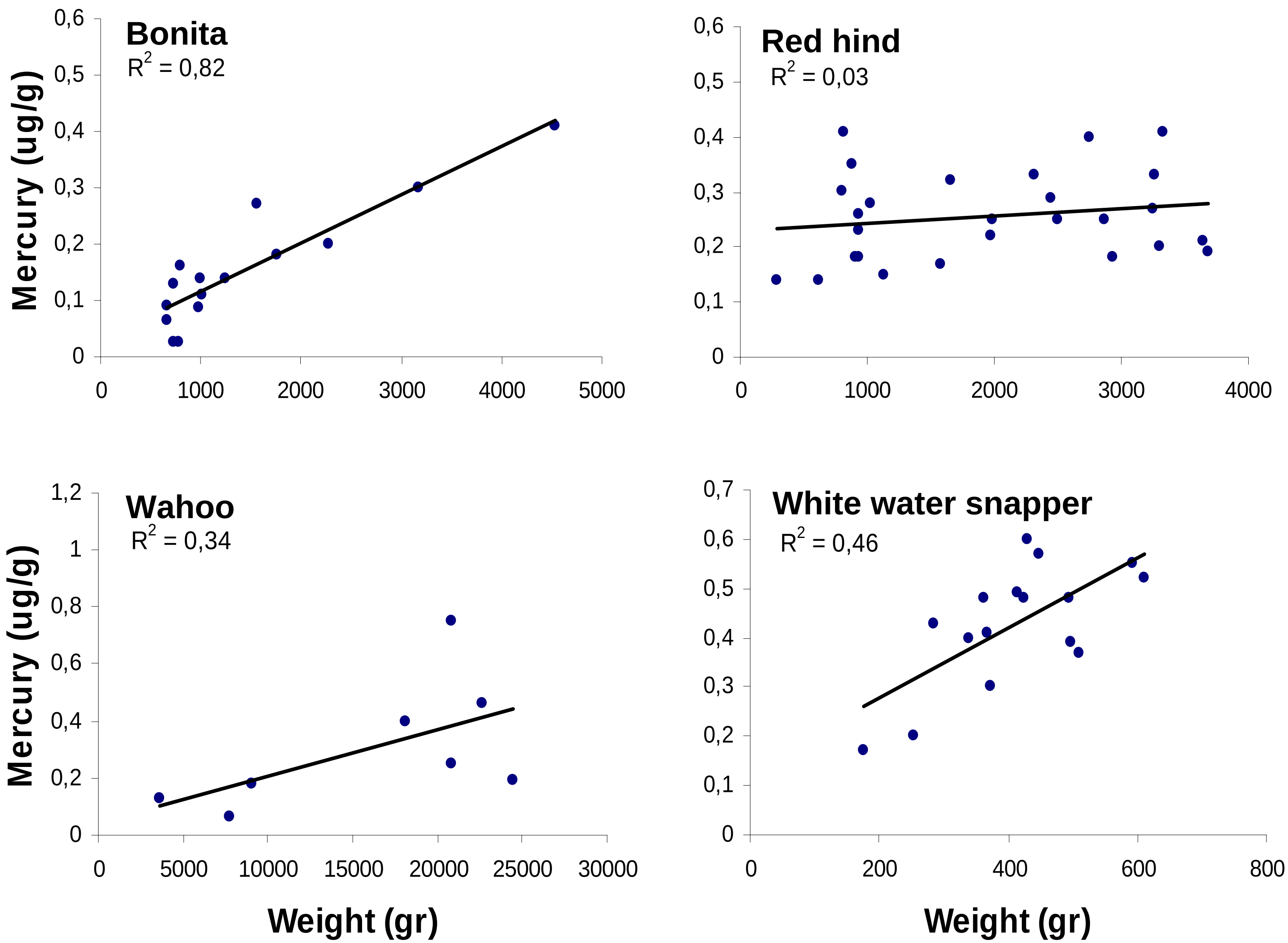
Do not consume: Species that should not be consumed during pregnancy.

Based on these categories, only four species for which we measured mercury content (Barber, Flying fish, Bermuda chub and Bermuda dolphin fish (Mahi Mahi) can be consumed every day without risk of reaching the PTWI. Most species investigated (25 out of 43) deserve very little restriction but it is recommended that not more than one portion of these fish be eaten per day. These include Wahoo and Yellowfin tuna. However, twelve species should be restricted in their consumption to one portion a week or less. This category includes all shark species investigated in this study. Finally, the consumption of Blue marlin and Swordfish should be avoided by women during their pregnancy as only one portion of these species will exceed the tolerable dose for at least one month.

It is important to note again that these guidelines presume that no other fish (local or imported) is eaten in the same period. Therefore one meal per week of fish from category “Strong or Severe restriction” would likely keep a pregnant woman below the recommended PTWI. However if any other fish meal, even from the “Limited or Little restriction” category, is consumed it would possibly push her above that limit. Pregnant and Nursing mothers need to assess their seafood consumption in a holistic manner when choosing which fish to consume, considering all the fish and seafood they eat both local and foreign. It is therefore recommended that pregnant women who are regular fish consumers consume only those species in the “Without Restriction” or “Limited or Little restriction” categories, and if so inclined, select those that are higher in Omega three fatty acids.

Correlations between fish weight and mercury content were determined in species for which sample size was sufficient ($n \geq 6$) and in which the mercury concentration of most samples was above the detection limit of 0.5 µg/g. The relationship between fish weight and mercury concentration in the flesh of 4 species are presented in Figure 2. These relationships varied greatly among species. Morphological features such as weight were a good predictor of flesh mercury content in Bonita, Ocean Robin and Turbot. A moderate association between fish weight and mercury levels was observed for Blue runner, Wahoo and White water snapper. Whereas an absence of association was observed for most species (Bermuda mackerel, Blue-striped grunt, Coney, Gray snapper, Red hind and Yellowfin tuna).

Figure 2: Relation between fish species' weight and mercury content



2. Selenium

Table 3 shows the selenium concentrations for 36 fish species in all available flesh samples. Amberjack, Anchovy and Blue marlin had the highest selenium levels whereas Bermuda chub. Longfin jack and Flying fish had the lowest concentrations. Correlations between mercury and selenium content for all species was moderate (*r* = 0.29).

Table 3: Selenium concentrations (μg/g) in the flesh of local fish species

COMMON NAME	SCIENTIFIC NAME	N	MEAN ± ST. DEV	RANGE
Amberjack	Seriola dumerili	7	1.33 ± 2.24	0.42 – 6.40
Anchovy	Sardinella anchovia	1	1.50	
Bar jack/Green jack	Caranx ruber	1	0.41	
Barber (Creole fish)	Paranthias furcifer	11	0.68 ± 0.12	0.47 – 0.86
Barracuda	Sphyraena barracuda	4	0.37 ± 0.12	0.29 – 0.54
Bermuda chub	Kyphosus sectatrix	14	0.24 ± 0.20	0.11 – 0.68
Bermuda mackerel	Euthynnus alletteratus	13	0.50 ± 0.22	0.33 – 0.50
Black grouper	Mycteroperca bonaci	3	0.45 ± 0.08	0.37 – 0.52
Blue marlin	Makaira nigricans	3	2.10 ± 0.35	1.90 – 2.50
Blue runner	Caranx fusus	10	0.40 ± 0.07	0.28 – 0.54
Blue-striped grunt	Haemulon sciurus	14	0.35 ± 0.05	0.23 – 0.47
Bone fish	Albula vulpes	1	0.68	
Bonita (Almaco jack)	Seriola rivoliana	14	0.48 ± 0.09	0.32 – 0.66
Caesar grunt	Haemulon carbonarum	1	0.46	
Coney	Cephalopholis fulva	17	0.55 ± 0.17	0.27 – 0.78
Dusky shark (Galapagos)	Carcharhinus galapagensis	2	0.56 ± 0.24	0.39 – 0.73
Flounder sp.	Bothus sp.	1	0.42	
Flying fish	Cypselurus heterurus	6	0.31 ± 0.04	0.26 – 0.38
Frys	Anchoa choerostoma	2	0.54 ± 0.09	0.47 – 0.60
Grasby	Epinephelus cruentatus	1	0.62	
Gray snapper	Lutjanus griseus	13	0.33 ± 0.05	0.25 – 0.42
Gummy shark (dogfish)	Mustelus antarcticus	1	0.47	
Gwelly	Pseudocaranx dentex	1	0.58	
Hogfish	Lachnolaimus maximus	5	0.32 ± 0.09	0.21 – 0.42
Hybrid coney-barber	Cephalopholis fulva/Paranthais furcifer	1	0.54	
Longfin jack/Bar Jack	Caranx ruber	1	0.28	

COMMON NAME	SCIENTIFIC NAME	N	MEAN ± ST. DEV	RANGE
Ocean robin	Decapterus macarellus	13	0.69 ± 0.19	0.41 – 0.95
Rainbow runner	Elagatis bipinnulata	2	0.43 ± 0.00	0.43 – 0.43
Red snapper	Lutjanus sp	2	0.46 ± 0.00	0.46 – 0.46
Tuna	Thunnus sp.	1	0.63	
Turbot	Balistes capriscus	7	0.36 ± 0.07	0.25 – 0.45
Wahoo	Acanthocybium solandri	7	0.86 ± 0.36	0.38 – 1.40
Whitewater (lane) snapper	Lutjanus synagris	16	0.39 ± 0.03	0.35 – 0.45
Yellowfin tuna	Thunnus albacares	2	0.64 ± 0.08	0.58 – 0.69
Yellowtail snapper	Ocyurus chrysurus	1	0.46	

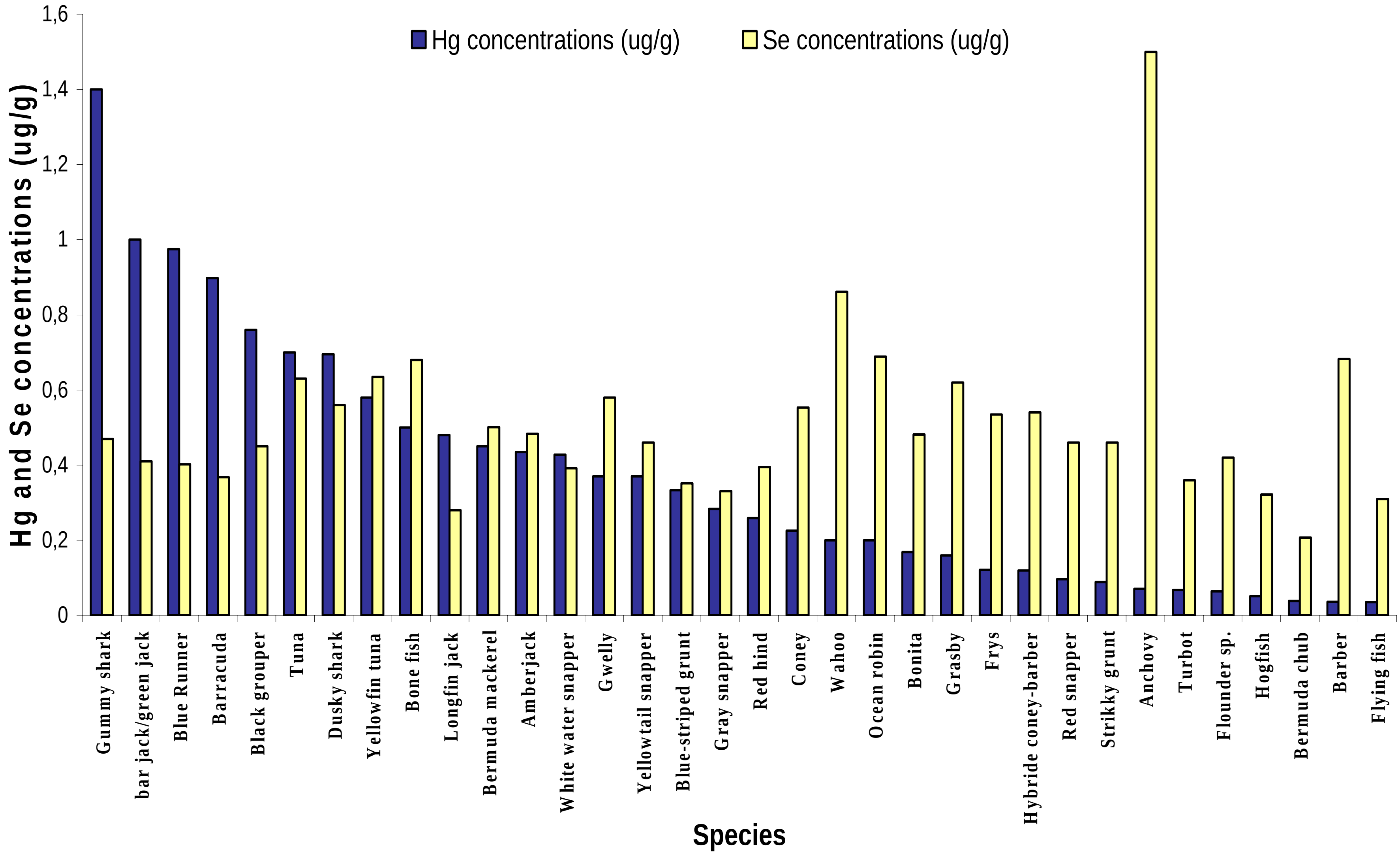
Selenium concentrations in the livers of 8 local species are reported in Table 4. The highest concentrations of selenium were found in Barbers and Bonitas and the lowest in Gwelly liver. Selenium concentrations in fish flesh were highly correlated with selenium liver levels (r = 0.64). The concentration of selenium in liver was always higher than levels measured in flesh. Interestingly, concentrations of mercury in livers were inversely correlated with selenium concentrations (r = - 0.24).

Table 4: Selenium concentrations in the liver of some local fish species

COMMON NAME	SCIENTIFIC NAME	TISSUE	N	MEAN ± ST. DEV	RANGE
Barber (Creole fish)	Paranthias furcifer	Liver	7	8.84 ± 2.57	6.20 – 14.00
Bermuda chub	Kyphosus sectator	Liver	8	2.75 ± 2.72	1.20 – 8.40
Bonita (Almaco jack)	Seriola rivoliana	Liver	2	4.45 ± 0.35	4.20 – 4.70
Coney	Cephalopholis fulva	Liver	13	3.52 ± 0.85	2.40 – 4.90
Dusky shark (Galapagos)	Carcharhinus galapagensis	Liver	1	5.20	
Gray snapper	Lutjanus griseus	Liver	2	2.25 ± 1.06	1.50 – 3.00
Gummy shark (dog fish)	Mustelus antarcticus	Liver	1	4.30	
Gwelly	Pseudocaranx dentex	Liver	1	0.98	

Figure 3 shows mercury and selenium concentrations in the flesh of 34 fish species in Bermuda. A small proportion of species had mercury concentrations superior to selenium levels. This is particularly the case for shark species, Bar jack, Blue runner, Barracuda and Black grouper. However, most species (25 out of 34) showed higher selenium than mercury concentrations. Among these, Anchovy and Barber have 21 and 19 times more selenium than mercury in their flesh, respectively.

Figure 3: Mercury and selenium content in flesh of local fish species



3. Omega (n-3) PUFA

The percentage of n-3 PUFA related to total fatty acid content and the concentration of n-3 PUFA (mg/220g of fish) in flesh of 34 local fish species is presented in Table 5. Flying fish, Amberjack and the hybrid of Coney-Barber had the highest percentage of n-3 PUFA related to total lipid or fat content whereas the Caesar grunt had the lowest percentage. Ocean robins had the greatest variation in the percentage of n-3 PUFA between fish samples. The highest concentration of n-3 PUFA was measured in Blue runner, Wahoo and Bermuda mackerel. These species were also those that had the largest range of n-3 PUFA concentrations (mg/220g of fish) between individuals of the same species. Hogfish, Red hind and Grasby had the lowest n-3 PUFA concentrations in their flesh. There is a very strong correlation (r = 0.98), shown in figure 5, between concentrations of n-3 PUFA and total lipids (fatness) in the flesh of local species. The precise fatty acid profile of all fish species is presented in the annex to this report. Omega-3 FAs represent between 20 and 49% of total fatty acids.

n-3 PUFA concentration (mg/220 g) was moderately but significantly correlated with mercury (r = 0.33) and selenium (r = 0.24) concentrations in flesh of the species studied.

Table 5: Percentage of n-3 PUFA concentrations in relation to total fatty acid contents and n-3 PUFA concentrations (mg/220g of flesh) in flesh of local fish species

COMMON NAME	SCIENTIFIC NAME	N	MEAN ± ST. DEV % N-3 PUFA	RANGE % N-3 PUFA	MEAN ± ST. DEV N-3 PUFA MG /220 G	RANGE N-3 PUFA MG /220 G
Amberjack	Seriola dumerili	6	46.2 ± 5.5	38.5 – 50.5	467 ± 73	373 – 590
Anchovy	Sardinella anchovia	1	43.5		1159	
Bar jack/green jack	Caranx Ruber	1	32.5		1422	
Barber (Creole fish)	Paranthias furcifer	11	29.4 ± 2.9	24.9 – 33.8	681 ± 192	454 – 1003
Barracuda	Sphyraena barracuda	4	34.0 ± 1.4	32.8 – 35.8	335 ± 108	176 – 415
Bermuda chub	Kyphosus sectator	13	25.0 ± 2.9	18.4 – 29.0	403 ± 347	162 – 1283
Bermuda mackerel	Euthynnus alletteratus	12	31.5 ± 5.0	20.9 – 31.5	2803 ± 3008	354 – 9385
Black grouper	Mycteroperca bonaci	3	24.6 ± 11.7	18.1 – 45.4	355 ± 218	150 – 720
Blue marlin	Makaira nigricans	3	34.9 ± 4.1	29.4 – 38.1	419 ± 481	142 – 1138
Blue Runner	Caranx fusus	10	28.0 ± 5.2	21.6 – 40.6	3801 ± 3043	492 – 12 287
Blue-striped grunt	Haemulon sciurus	14	27.0 ± 5.6	15.9 – 35.5	337 ± 113	155 – 593
Bone fish	Albula vulpes	1	27.7		876	
Bonita (Almaco Jack)	Seriola rivoliana	14	42.8 ± 6.3	30.3 – 49.6	537 ± 246	302 – 1183
Coney	Cephalopholis fulva	17	31.9 ± 5.8	21.9 – 40.1	520 ± 536	160 – 2097
Dusky shark (Galapagos)	Carcharhinus galapagensis	2	27.4 ± 1.5	25.5 – 28.6	283 ± 62	240 – 373
Flounder sp.	Bothus sp.	1	31.1		386	
Flying fish	Cypselurus heterurus	5	48.8 ± 2.0	44.9 – 50.4	829 ± 233	587 – 1148
Fry	Anchoa choerostoma	2	44.3 ± 3.6	41.8 – 46.9	1130 ± 8	1124 – 1136

COMMON NAME	SCIENTIFIC NAME	N	MEAN ± ST. DEV % N-3 PUFA	RANGE % N-3 PUFA	MEAN ± ST. DEV N-3 PUFA MG /220 G	RANGE N-3 PUFA MG /220 G
Grasby	Epinephelus cruentatus	1	31.5		244	
Gummy shark (dogfish)	Mustelus antarcticus	1	31.0		315	
Gwelly	Pseudocaranx dentex	1	33.7		295	
Hogfish	Lachnolaimus maximus	5	23.2 ± 6.5	15.0 – 32.4	201 ± 17	182 – 227
Hybrid coney-barber	Cephalopholis fulva/Paranthais furcifer	1	45.2		390	
Longfin jack	Caranx ruber	1	24.5		2239	
Ocean robin	Decapterus macarellus	13	37.2 ± 9.0	14.1 – 50.7	534 ± 344	36 – 1391
Rainbow runner	Elagatis bipinnulata	2	44.2 ± 1.9	42.9 – 45.5	544 ± 24	527 – 561
Red hind	Epinephelus guttatus	26	20.4 ± 4.3	11.5 – 28.2	201 ± 65	123 – 353
Red snapper	Lutjanus sp	2	39.9 ± 9.7	31.2 – 49.0	328 ± 63	251 – 406
Caesar grunt	Haemulon carbonarum	1	11.7		865	
Tuna	Thunnus sp.	1	29.1		1006	
Turbot	Balistes capriscus	7	39.4 ± 4.7	31.6 – 44.3	299 ± 39	253 – 361
Wahoo	Acanthocybium solandri	7	39.1 ± 3.3	34.8 – 43.2	3816 ± 4219	264 – 9858
Whitewater (lane) snapper	Lutjanus synagris	15	28.9 ± 5.3	16.9 – 38.7	412 ± 114	216 – 713
Yellowfin tuna	Thunnus albacares	2	40.7 ± 5.0	36.0 – 45.9	321 ± 217	190 – 572
Yellowtail snapper	Ocyurus chrysurus	1	35.9		519	

Figure 4 shows mercury and n-3 PUFA flesh concentrations in 35 fish species from Bermuda. While the flesh of some species like Marlin and Shark contain high concentrations of mercury with low n-3 PUFA concentrations, others like Blue runner, Longfin jack and Bermuda mackerel show relatively high to moderate mercury content with elevated n-3 PUFA concentrations. Wahoo Flesh contains the highest n-3 PUFA concentration, while mercury levels appeared to be relatively moderate.

Figure 4: Mercury and n-3-PUFA content in flesh of local fish species

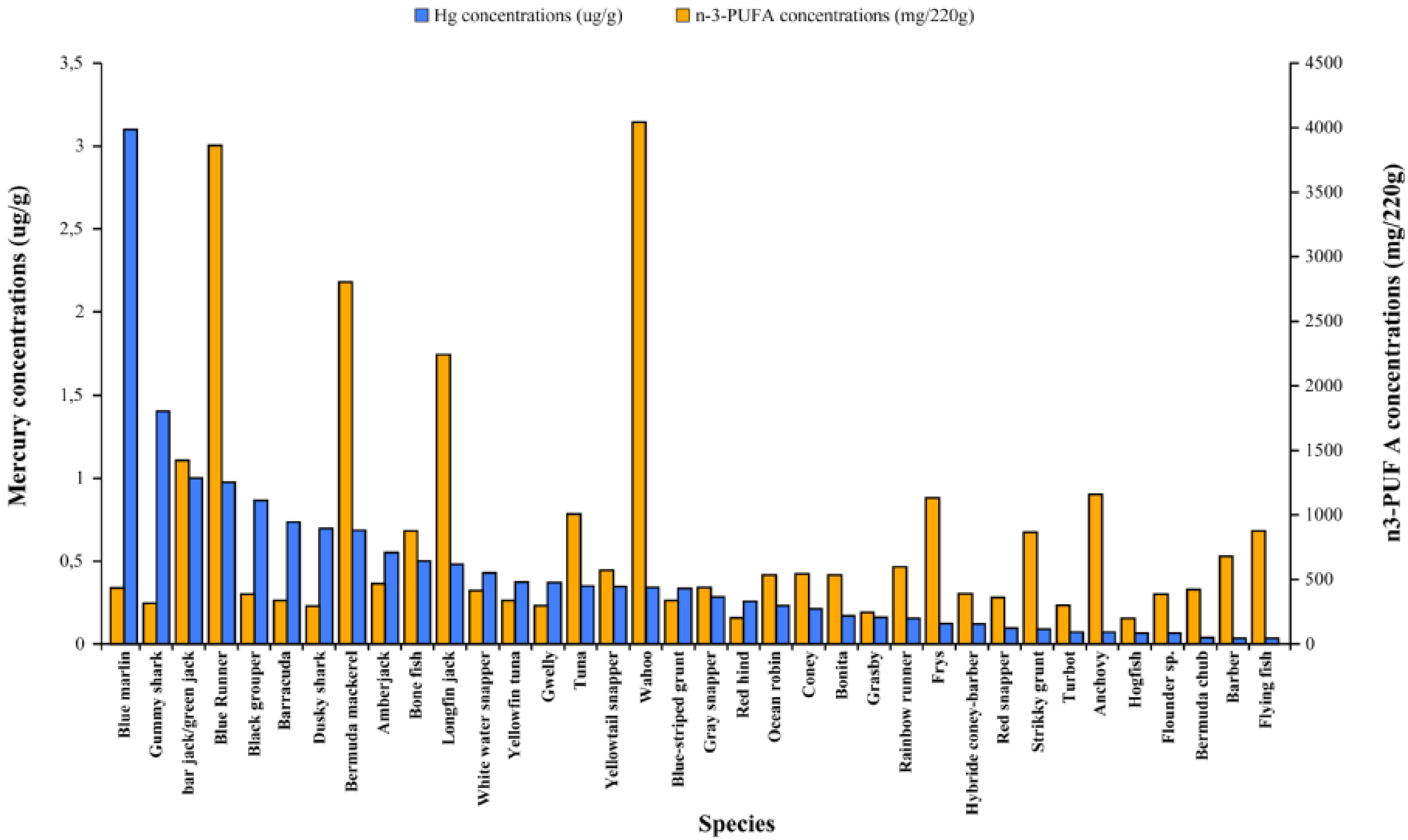
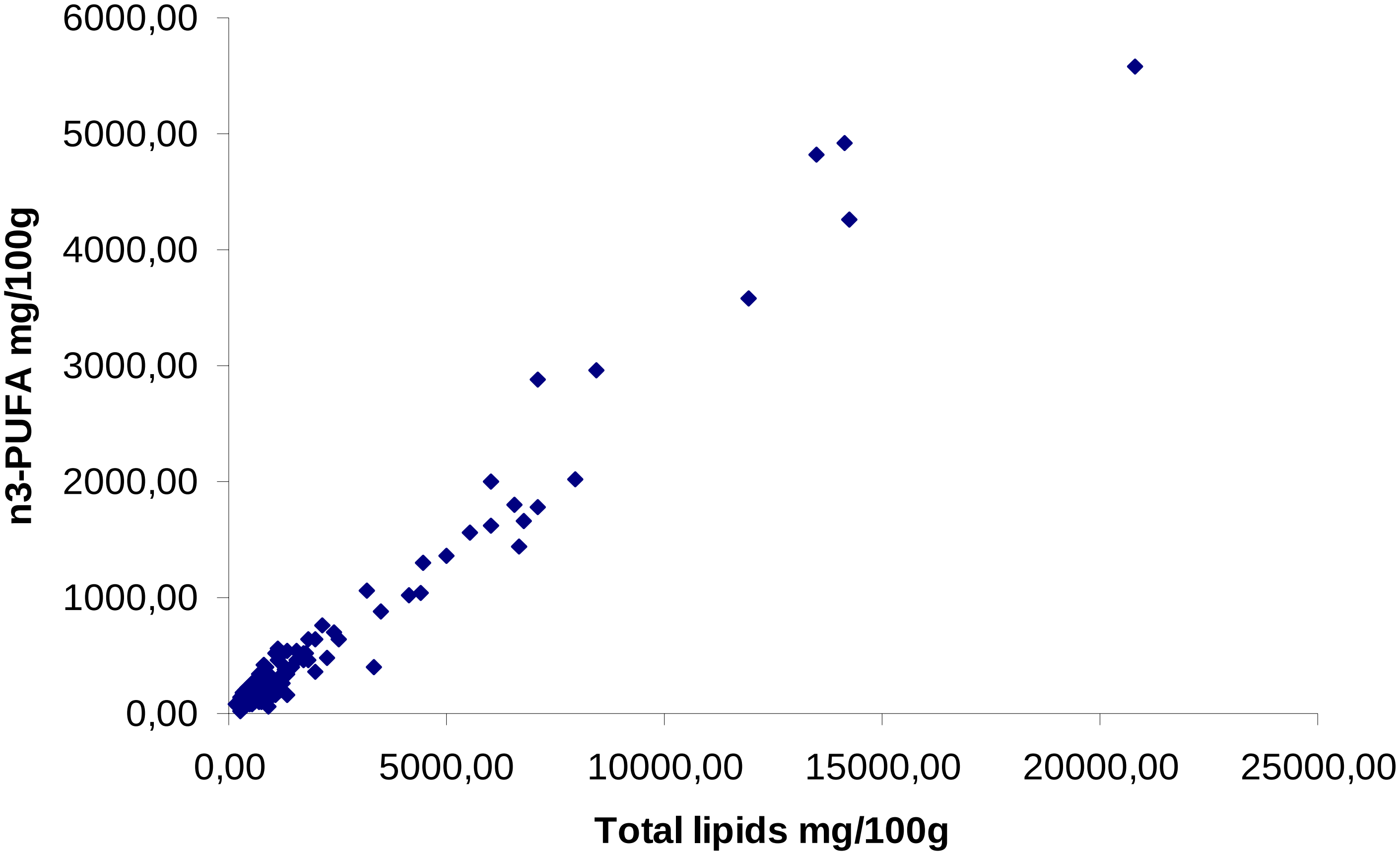


Figure 5: Relationship between n3-PUFA and total lipids content in flesh of local fish species



Discussion

In this study, we determined the mercury content as well as selenium and n-3 PUFA concentrations in a number of Bermudian fish species to evaluate the risk and benefit of their consumption during pregnancy in order to protect the developing foetus.

As found in other studies (Mahaffey et al. 2004; Storelli and Marcotrigiano 2000), high-end predatory fish such as Swordfish and Blue Marlin have very high mercury content in their flesh. Shark livers also appear to retain mercury. Therefore, as recommended by other agencies (U.S. Department of Health and Human Services and U.S. Environmental Protection Agency 2004), these species as well as King Mackerel and Tilefish, that were not included in our study, should not be consumed by women planning to become pregnant, those that are pregnant or breastfeeding. Moreover, analysis of selenium and n3-PUFA content did not reveal any particular nutritional benefit associated with their consumption. A number of other species should also be consumed with moderation, i.e between once per week and once per month, as their flesh contained moderately high concentrations of mercury.

We previously conducted a study aiming to assess umbilical cord blood concentrations of environmental contaminants, including mercury (Dewailly and Pereg 2004). Results showed a higher than expected mean mercury concentration of 41.3 nmol/l eight times the US average measured among women of childbearing age in 2000 (Mahaffey et al. 2004). An accompanying fish consumption frequency questionnaire administrated to the pregnant women in the study revealed that 19%, 17% and 12% of them had consumed on regular basis locally caught Wahoo, Snapper and Tuna, respectively. Furthermore, a positive correlation ($r = 0.50$) was found between Wahoo and Snapper consumption with cord blood mercury content. In the present study, all snapper species, except the deep water red snapper (*Etelis oculatus*), Wahoo and Tuna, were categorised in the "**limited restrictions**" frequency consumption category based on their flesh mercury concentration. Therefore, consumption of any one of those species during pregnancy should be restricted to one fish meal per day to one meal per week in order to reduce the exposure of the foetus to methylmercury in the Bermudian population.

Selenium concentrations were found to be high in all fish species with a relative narrow variation (0.24-2.1 µg/g). The daily nutrient intake for selenium is between 50 and 70 µg/day. Significantly a single 220 g meal of Bermuda fish will provide between 53 and 460 µg/day.

While this sampling covers a wide range of fish species, it is of importance to note that sample size within each category of species is limited, oftentimes to a single sample. Ranges of concentrations were sometimes very wide, particularly for n3-PUFA and smaller sample sizes offer less confidence.

Tropical fish are often considered to be lean with little omega-3 content when compared to cold-water fish. However, if we consider an optimal dietary intake of 400-1500 mg/day, most Bermudian fish analysed in this study will provide the recommended targets. Some species are particularly high in omega-3 content (Bermuda mackerel, Wahoo, Blue runner). However, these fish also show the highest variation in content. Further studies will hopefully reveal the mechanisms that result in such variability (water temperature, season, physiological state (spawning) etc).

The investigation of mercury levels in Bermuda fish has been carried out along with an evaluation of two key nutrients, omega three fatty acids and the mineral selenium, in order to help in the preparation of balanced Bermuda fish consumption advisories. Pregnant and nursing mothers and Bermuda's obstetricians can use such a guide to decide which local fish to consume and which to avoid during pregnancy.

These data on balancing risk and benefits from Bermuda fish consumption need to be released to the Bermuda population, particularly to pregnant women. It is now possible to minimize the risk due to mercury exposure while maintaining the nutritional benefit of fish consumption. However, while recommending eating more or less of specific Bermuda fish their individual sustainability in the Bermuda environment should be assessed.

The data used to make the above recommendations are part of ongoing studies, both internationally and locally, that aim to characterise mercury in the marine environment and its effects on human health. It is important to note that there is natural variability within species groups and sometimes between specimens from the same fish. There are important and interesting questions that still need to be answered about the variability and potential seasonality of both mercury and fat levels in local fish that require more research In addition the sample size for some species has been limited and some species still need to be sampled. As more data become available the recommendations made here should be assessed and updated when necessary.

Acknowledgments

This work would not have been possible without the financial support of the Lepercq Foundation and we would like to thank Mrs. Françoise Lepercq for her long standing support.

The Bermuda Government provided ship and boat time and we are very grateful to the Department of Conservation Services and their staff for their collaboration and scientific support. We also would like to recognize the support and expertise of the Bermuda Fisheries Department (Dr. Tom Sleeter, Dr. Tammy Trott, Dr. Brian Luckhurst, Mr. John Edmunds and Mr. Craig Trott). The Bermuda Underwater Exploration Institute (BUEI) with Mr Teddy Tucker also provided boat support and meeting facilities and the Bermuda Institute for Ocean Science (BIOS) provided accommodation and freezer storage for visiting scientists and fieldworkers.

Finally we thank all the Bermudian commercial fishermen who have helped us in collecting fish samples.

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ANNEX 1

FATTY ACID PROFILES OF BERMUDA FISH

FISH SPECIES					
COMMON NAME	Amberjack	Anchovy	Bar jack/green jack	Barber (Creole fish)	Barracuda
SCIENTIFIC NAME	*Seriola dumerili*	*Sardinella anchovia*	Caranx ruber	*Paranthias furcifer*	*Sphyraena barracuda*
N	6	1	1	11	4
FATTY ACIDS					
C16:0 Mean ± std	22.97 ± 0.68	22.91	23.56	25.76 ± 1.22	22.87 ± 0.61
C18:0	9.41 ± 0.91	7.21	7.69	7.33 ± 0.48	10.26 ± 0.37
C20:0	0.05 ± 0.13	0.36	0.39	0.37 ± 0.17	0.08 ± 0.15
C20:1 (sum)	0.58 ± 0.37	0.34	0.73	1.30 ± 0.14	0.31 ± 0.22
C20:3 n3	0.87 ± 1.58	0.00	0.30	0.09 ± 0.11	0.09 ± 0.17
C20:4 n6	3.51 ± 2.07	1.66	2.95	3.64 ± 0.56	7.82 ± 0.98
C20:5 n3	2.94 ± 1.38	6.26	3.92	4.83 ± 0.56	3.05 ± 0.66
C22:3 n3	0.29 ± 0.78	0.00	0.00	0.007 ± 0.020	0.00 ± 0.00
C24:1 n9	1.52 ± 0.46	1.53	0.71	0.94 ± 0.17	1.22 ± 0.20
C22:4 n6	1.12 ± 0.91	0.51	1.07	0.77 ± 0.09	1.67 ± 0.19
C22:5 n6	2.55 ± 0.33	1.74	2.32	3.87 ± 0.85	3.00 ± 0.21
C22:5 n3	9.25 ± 17.22	0.96	2.86	2.05 ± 0.15	2.89 ± 0.59
C22:6 n3	32.71 ± 16.48	34.14	21.98	20.19 ± 2.68	27.40 ± 2.22
n-6 total	8.77 ± 1.98	6.51	9.45	10.37 ± 1.55	14.93 ± 1.08
n-3 total	46.17 ± 5.15	43.54	32.47	29.44 ± 2.90	33.95 ± 1.40
n-3/n-6	5.56 ± 1.63	6.69	3.44	2.86 ± 0.23	2.28 ± 0.22
Saturated	33.19 ± 1.64	34.81	36.26	37.67 ± 1.47	34.35 ± 0.05
Monounsaturated	11.87 ± 2.87	15.14	21.82	22.52 ± 3.22	16.76 ± 1.49
Polyunsaturated	54.94 ± 4.26	50.05	41.92	39.81 ± 4.29	48.88 ± 1.45

FISH SPECIES					
COMMON NAME	Bermuda chub	Bermuda mackerel	Black grouper	Blue marlin	Blue runner
SCIENTIFIC NAME	*Kyphosus sectator*	*Euthynnus alletteratus*	*Mycteroperca bonaci*	*Makaira nigricans*	*Caranx fusus*
N	15	12	3	4	11
FATTY ACIDS					
C16:0 Mean ± std	23.30 ± 3.46	24.56 ± 2.77	55.46 ± 68.15	19.27 ± 2.08	24.45 ± 1.42
C18:0	7.94 ± 1.02	9.93 ± 2.72	17.48 ± 21.57	10.43 ± 0.89	9.46 ± 2.02
C20:0	0.18 ± 0.19	0.41 ± 0.15	0.80 ± 1.13	0.16 ± 0.19	0.39 ± 0.02
C20:1 (sum)	0.89 ± 0.58	0.61 ± 0.30	2.18 ± 1.87	0.94 ± 0.60	0.88 ± 0.23
C20:3 n3	0.03 ± 0.08	0.09 ± 0.10	0.61 ± 1.15	0.05 ± 0.11	0.04 ± 0.06
C20:4 n6	11.68 ± 5.39	3.62 ± 1.17	8.06 ± 4.66	5.37 ± 2.65	2.15 ± 0.46
C20:5 n3	6.81 ± 1.92	4.23 ± 1.10	2.48 ± 1.73	4.87 ± 0.91	3.25 ± 0.36
C22:3 n3	0.004 ± 0.017	0.009 ± 0.022	0.27 ± 0.55	0.00 ± 0.00	0.006 ± 0.018
C24:1 n9	0.93 ± 0.20	0.72 ± 0.39	0.68 ± 0.41	2.69 ± 1.19	0.65 ± 0.30
C22:4 n6	3.34 ± 1.53	0.77 ± 0.16	4.02 ± 1.32	0.64 ± 0.29	0.72 ± 0.11
C22:5 n6	1.66 ± 0.84	2.08 ± 0.76	4.52 ± 5.84	2.82 ± 1.22	1.72 ± 0.35
C22:5 n3	5.49 ± 2.03	2.09 ± 0.47	5.33 ± 4.27	1.91 ± 0.06	2.09 ± 0.18
C22:6 n3	9.87 ± 3.65	22.58 ± 5.49	13.38 ± 4.46	27.46 ± 4.59	20.54 ± 5.65
n-6 total	21.67 ± 7.56	9.86 ± 1.80	24.12 ± 8.77	11.30 ± 4.22	7.05 ± 0.99
n-3 total	25.03 ± 2.89	31.47 ± 5.02	24.64 ± 11.68	34.95 ± 4.10	28.01 ± 5.15
n-3/n-6	1.37 ± 0.72	3.26 ± 0.72	1.00 ± 0.09	3.47 ± 1.36	4.00 ± 0.63
Saturated	33.84 ± 3.89	39.06 ± 4.06	85.57 ± 110.70	31.87 ± 2.54	37.57 ± 1.05
Monounsaturated	17.17 ± 7.91	18.10 ± 6.28	66.96 ± 95.50	21.88 ± 5.81	27.37 ± 5.63
Polyunsaturated	41.21 ± 17.14	38.15 ± 12.91	48.75 ± 20.43	46.24 ± 8.32	35.06 ± 5.81

FISH SPECIES					
COMMON NAME	Blue-striped grunt	Bone fish	Bonita (Almaco jack)	Coney	Dusky shark (Galapagos)
SCIENTIFIC NAME	*Haemulon sciurus*	*Albula vulpes*	*Seriola rivoliana*	*Cephalopholis fulva*	*Carcharhinus galapagensis*
N	14	1	14	18	4
FATTY ACIDS					
C16:0 Mean ± std	21.15 ± 2.21	25.24	22.26 ± 1.00	22.08 ± 1.84	16.15 ± 1.97
C18:0	9.99 ± 1.28	7.82	10.15 ± 1.22	9.38 ± 1.38	13.86 ± 1.64
C20:0	0.38 ± 0.27	0.27	0.17 ± 0.18	0.25 ± 0.21	0.14 ± 0.17
C20:1 (sum)	1.41 ± 0.92	1.24	0.46 ± 0.49	0.87 ± 0.41	1.87 ± 1.16
C20:3 n3	0.17 ± 0.23	0.21	0.04 ± 0.11	0.01 ± 0.06	0.00 ± 0.00
C20:4 n6	9.74 ± 2.38	3.36	3.62 ± 1.29	7.19 ± 3.61	7.31± 2.87
C20:5 n3	5.21 ± 1.31	4.49	3.86 ± 0.58	3.22 ± 0.63	2.42 ± 0.76
C22:3 n3	0.00 ± 0.00	0.00	0.00	0.05 ± 0.02	0.49 ± 0.98
C24:1 n9	0.50 ± 0.18	0.24	1.82 ± 0.36	1.75 ± 0.23	0.81 ± 0.20
C22:4 n6	2.73 ± 0.94	0.79	0.55 ± 0.43	1.94 ± 1.21	4.73 ± 3.41
C22:5 n6	2.67 ± 0.72	1.26	2.49 ± 0.45	3.13 ± 0.72	2.35 ± 0.47
C22:5 n3	2.97 ± 0.74	1.91	2.01 ± 0.38	2.34 ± 0.23	3.28 ± 0.91
C22:6 n3	17.02 ± 5.35	18.83	36.17 ± 7.21	25.19 ± 6.28	20.71± 0.81
n-6 total	18.14 ± 3.04	7.84	8.21 ± 2.06	14.49 ± 5.04	16.01± 6.67
n-3 total	26.97 ± 5.58	27.67	42.76 ± 6.31	31.63 ± 6.14	27.35 ± 1.53
n-3/n-6	1.51 ± 0.35	3.53	5.44 ± 1.33	2.48 ± 0.96	1.97 ± 0.86
Saturated	33.75 ± 2.51	36.28	34.01 ± 1.33	34.20 ± 2.41	31.34 ± 1.35
Monounsaturated	21.15 ± 4.97	28.21	15.01 ± 7.21	19.68 ± 5.42	25.29 ± 5.54
Polyunsaturated	45.11 ± 7.10	35.51	50.98 ± 6.84	46.12 ± 7.02	43.37 ± 5.14

FISH SPECIES					
COMMON NAME	Flounder sp.	Flying fish	Fry	Grasby	Gray snapper
SCIENTIFIC NAME	Bothus sp.	*Cypselurus heterurus*	*Anchoa choerostoma*	Epinephelus cruentatus	*Lutjanus griseus*
N	1	7	2	1	13
FATTY ACIDS					
C16:0 Mean ± std	21.15	21.20 ± 1.36	21.09 ± 0.43	20.08	21.89 ± 0.85
C18:0	8.75	10.04 ± 1.58	7.99 ± 0.34	9.97	9.52 ± 0.64
C20:0	0.40	0.24 ± 0.11	0.42 ± 0.01	0.34	0.20 ± 0.17
C20:1 (sum)	0.53	0.57 ± 0.23	0.32 ± 0.03	0.68	0.70 ± 0.14
C20:3 n3	0.00	0.02 ± 0.06	0.23 ± 0.03	0.00	0.00 ± 0.00
C20:4 n6	10.03	1.80 ± 0.46	2.88 ± 1.41	8.65	5.45 ± 1.58
C20:5 n3	8.15	3.98 ± 0.56	7.06 ± 0.43	4.04	2.81 ± 0.35
C22:3 n3	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00
C24:1 n9	0.67	1.25 ± 0.14	1.28 ± 0.32	2.75	1.09 ± 0.29
C22:4 n6	2.46	0.18 ± 0.13	0.54 ± 0.22	2.24	1.59 ± 0.44
C22:5 n6	1.88	2.08 ± 0.10	1.56 ± 0.08	3.83	2.64 ± 0.43
C22:5 n3	4.19	1.54 ± 0.16	1.01 ± 0.11	2.22	2.18 ± 0.18
C22:6 n3	17.76	42.50 ± 2.80	33.54 ± 3.71	24.01	26.56 ± 4.67
n-6 total	17.69	6.20 ± 0.57	7.56 ± 1.59	16.64	11.92 ± 2.35
n-3 total	31.14	48.79 ± 1.96	44.31 ± 3.62	31.45	32.70 ± 4.42
n-3/n-6	1.76	7.92 ± 0.69	6.04 ± 1.75	1.89	2.88 ± 0.83
Saturated	32.55	32.90 ± 0.79	33.35 ± 0.70	32.62	33.27 ± 0.90
Monounsaturated	18.62	10.59 ± 4.70	14.77 ± 2.73	19.28	22.11 ± 3.62
Polyunsaturated	48.83	48.12 ± 19.54	51.88 ± 2.03	48.10	44.62 ± 4.01

Fish species					
Common name	Gwelly	Hogfish	Hybrid coney-barber	Longfin jack	Ocean robin
Scientific name	*Pseudocaranx dentex*	*Lachnolaimus maximus*	*Cephalopholis fulva*	Caranx ruber	*Decapterus macarellus*
N	1	7	1	1	13
Fatty acids					
C16:0 Mean ± std	20.45	20.96 ± 0.98	20.86	30.46	24.34 ± 13.92
C18:0	9.30	8.94 ± 0.26	9.01	7.38	14.01 ± 8.42
C20:0	0.46	0.35 ± 0.19	0.00	0.36	0.26 ± 0.22
C20:1 (sum)	0.36	0.89 ± 0.83	0.64	0.49	0.60 ± 0.37
C20:3 n3	0.00	0.15 ± 0.21	0.00	0.32	0.03 ± 0.08
C20:4 n6	10.10	15.07 ± 2.82	4.76	2.78	2.69 ± 0.95
C20:5 n3	6.35	3.92 ± 1.68	4.42	2.90	4.86 ± 2.02
C22:3 n3	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00
C24:1 n9	1.68	0.96 ± 0.21	1.73	0.60	1.45 ± 0.62
C22:4 n6	1.37	3.02 ± 0.59	0.70	0.73	0.81 ± 1.57
C22:5 n6	2.46	3.21 ± 0.90	4.89	1.14	2.19 ± 0.79
C22:5 n3	2.07	2.26 ± 0.27	1.83	1.83	2.29 ± 1.25
C22:6 n3	25.23	15.75 ± 5.35	38.21	18.01	29.04 ± 9.07
n-6 total	15.71	25.06 ± 3.79	12.20	7.29	8.05 ± 2.00
n-3 total	33.66	23.23 ± 6.50	45.19	24.51	37.17 ± 8.99
n-3/n-6	2.14	0.97 ± 0.41	3.71	3.36	4.88 ± 1.40
Saturated	32.41	34.75 ± 2.14	30.39	41.05	42.84 ± 27.67
Monounsaturated	18.22	16.97 ± 2.98	12.22	27.15	21.29 ± 12.71
Polyunsaturated	49.37	48.29 ± 4.73	57.39	31.81	45.23 ± 8.58

Fish species					
Common name	Rainbow runner	Red hind	Red snapper	Caesar grunt	Tuna
Scientific name	*Elagatis bipinnulata*	*Epinephelus guttatus*	*Lutjanus sp*	Haemulon carbonarum	*Thunnus sp.*
N	2	26	4	1	1
Fatty acids					
C16:0 Mean ± std	19.43 ± 0.47	23.54 ± 2.71	22.13 ± 1.33	29.04	20.62
C18:0	9.73 ± 0.79	8.68 ± 1.91	8.86 ± 0.87	8.75	8.03
C20:0	0.20 ± 0.29	0.28 ± 0.23	0.19 ± 0.22	0.66	0.38
C20:1 (sum)	0.64 ± 0.27	0.94 ± 0.37	0.51 ± 0.13	4.74	1.93
C20:3 n3	0.00 ± 0.00	0.01 ± 0.05	0.00 ± 0.00	0.50	0.31
C20:4 n6	3.55 ± 0.02	13.37 ± 3.03	4.48 ± 0.85	5.18	2.37
C20:5 n3	5.35 ± 0.15	2.91 ± 0.61	4.69 ± 1.05	3.48	4.71
C22:3 n3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00
C24:1 n9	1.51 ± 0.13	1.40 ± 0.38	1.25 ± 0.37	0.00	1.17
C22:4 n6	0.41 ± 0.01	4.00 ± 0.77	1.04 ± 0.27	2.96	0.44
C22:5 n6	2.32 ± 0.14	2.19 ± 0.64	2.83 ± 0.58	0.91	1.41
C22:5 n3	2.04 ± 0.04	3.10 ± 0.49	2.68 ± 0.89	2.69	1.91
C22:6 n3	35.65 ± 2.33	13.81 ± 4.17	32.02 ± 11.64	3.88	21.20
n-6 total	7.99 ± 0.03	22.34 ± 3.73	10.08 ± 0.69	12.05	6.20
n-3 total	44.24 ± 1.85	20.37 ± 4.27	39.90 ± 9.66	11.74	29.09
n-3/n-6	5.54 ± 0.21	0.93 ± 0.22	4.00 ± 1.13	0.97	4.69
Saturated	30.82 ± 0.71	35.17 ± 3.75	33.03 ± 3.78	41.99	30.85
Monounsaturated	16.95 ± 2.59	22.12 ± 3.51	16.99 ± 5.56	34.22	33.87
Polyunsaturated	52.23 ± 1.88	42.71 ± 6.50	49.98 ± 9.30	23.79	35.29

FISH SPECIES					
COMMON NAME	Turbot	Wahoo	White water (lane) snapper	Yellowfin tuna	Yellowtail snapper
SCIENTIFIC NAME	*Balistes capriscus*	*Acanthocybium solandri*	*Lutjanus synagris*	*Thunnus albacares*	*Ocyurus chrysurus*
N	2	9	15	3	1
FATTY ACIDS					
C16:0 Mean ± std	16.22 ± 1.48	21.96 ± 1.42	21.15 ± 6.21	18.23 ± 2.36	21.32
C18:0	11.37 ± 0.68	7.41 ± 2.02	8.43 ± 2.20	11.27 ± 1.79	8.41
C20:0	0.00 ± 0.00	0.22 ± 0.13	0.35 ± 0.20	0.00 ± 0.00	0.47
C20:1 (sum)	0.58 ± 0.59	1.05 ± 0.39	0.73 ± 0.40	0.69 ± 0.30	0.67
C20:3 n3	0.00 ± 0.00	0.15 ± 0.18	0.01 ± 0.05	0.00 ± 0.00	0.22
C20:4 n6	11.47 ± 2.53	3.25 ± 1.58	6.89 ± 1.83	5.42 ± 1.32	3.79
C20:5 n3	6.23 ± 0.93	5.87 ± 1.22	3.50 ± 0.59	4.10 ± 0.23	3.40
C22:3 n3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00
C24:1 n9	0.82 ± 0.43	1.44 ± 0.89	0.83 ± 0.25	2.66 ± 0.45	0.93
C22:4 n6	1.19 ± 0.87	0.43 ± 0.15	1.83 ± 0.39	0.57 ± 0.04	1.13
C22:5 n6	2.22 ± 0.39	1.78 ± 0.55	2.49 ± 0.66	3.63 ± 0.44	2.86
C22:5 n3	2.80 ± 1.04	1.84 ± 0.38	2.36 ± 0.37	1.29 ± 0.18	2.28
C22:6 n3	30.09 ± 5.42	29.96 ± 4.86	22.03 ± 5.31	35.32 ± 4.86	28.29
n-6 total	16.24 ± 3.29	7.38 ± 1.86	13.80 ± 2.46	11.39 ± 1.51	10.56
n-3 total	39.37 ± 4.65	39.08 ± 3.32	28.91 ± 5.34	40.72 ± 4.96	35.88
n-3/n-6	2.55 ± 0.74	5.53 ± 1.07	2.12 ± 0.33	3.65 ± 0.95	3.40
Saturated	28.17 ± 1.30	31.41 ± 2.54	32.51 ± 8.30	30.26 ± 1.65	33.21
Monounsaturated	16.22 ± 1.67	22.13 ± 6.65	23.23 ± 10.23	17.63 ± 2.64	20.34
Polyunsaturated	55.61 ± 2.15	46.45 ± 4.97	40.04 ± 12.72	52.11 ± 3.84	46.44

C20 :1 sum :	11c-20:1 n9, 11t-20:1 n9, 8c-20:1 n12
n-6 total :	9t12t-18:2 n6, 9t12c-18:2 n6, 9c12t-18:2 n6, 9c12c-18:2 n6, 6c9c12c-18:3 n6, 11c14c-20:2 n6, 8c11c14c-20:3 n6, 5c8c11c14c-20:4 n6, 13c16c-22:2 n6, 7c10c13c16c-22:4 n6, 4c7c10cx13c16c-22:5 n6
n-3 total :	9t12t15t-18:3 n3, 9c12c15c-18:3 n3, 6c9c12c15c-18:4 n3, 11c14c17c-20:3 n3, 8c11c14c17c-20:4 n3, 5c8c11c14c17c-20:5 n3, 13c16c19c-22:3 n3, 7c10c13c16c19c-22:5 n3, 4c7c10c13c16c19c-22:6n3
n-3/n-6 :	n-3 total/n-6 total
Saturated :	14:0, 18:0, 20:0, 22:0, 24:0
Monounsaturated :	9t-14:1 n5, 9t-16:1 n7, 6t-18:1 n12, 9t-18:1 n9, 11t-18:1 n7, 11t-20:1 n9, 9c-14:1 n5, 9c-16:1 n7, 6c-18:1 n12, 8c-20:1 n12, 9c-18:1 n9, 11c-18:1 n7, 11c-20:1 n9, 13c-22:1 n9, 15c-24:1 n9
Polyunsaturated :	9t12t15t-18:3 n3, 9t12t-18:2 n6, 9t12t-18:2 n6, 9c12t-18:2 n6, 9c12c15c-18:3 n3, 6c9c12c15c-18:4 n3, 11c14c17c-20:3 n3, 8c11c14c17c-20:4 n3, 5c8c11c14c17c-20:5 n3, 13c16c19c-22:3 n3, 7c10c13c16c19c-22:5 n3, 4c7c10c13c16c19c-22:6n3, 9c12c-18:2 n6, 6c9c12c-18:3 n6, 11c14c-20:2 n6, 8c11c14c-20:3 n6, 5c8c11c14c-20:4 n6, 13c16c-22:2 n6, 7c10c13c16c-22:4 n6, 4c7c10cx13c16c-22:5 n6