Selenium Health Benefit Values and Mercury Content of Alaska's Pacific Halibut: Ecological and Human Health Implications

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Objectives:

- Determine Se:Hg molar ratios and Se health benefit values for marine fish from two areas in Alaskan waters
- Examine the differences and variation between and within species and locations
- Discuss health and ecological implications in light of the data presented

Background:

- Consumption of fish is the main route of exposure to methylmercury (MeHg) for humans and other piscivorous animals
- MeHg is the most toxic form of Hg and it bioaccumulates and biomagnifies in the food chain
- MeHg has a high affinity for selenium (Se) and binds to selenoproteins which are essential to the normal function and development of the central nervous system (Carvalho 2008, Khan and Wang 2009
- Se is an essential dietary element that is homeostatically regulated but can be toxic in high concentrations and has been shown to provide protection from Hg toxicity when its molar mass exceeds that of Hg (Kaneko and Ralston 2007)
- The health benefits of eating fish low in mercury and high in Omega-3 fatty acids, Se, and other micronutrients is well established
- Some fish consumption advisories target long lived, large predatory fish including halibut, lingcod and salmon sharks and are based solely on Hg
- The most recent State and Federal recommendations for fish consumption appropriately weigh mercury tissue concentrations against the health benefits of high quality nutrients in fish when developing risk assessment models.

Methods:

1) Fish were collected between 2001 and 2014 and muscle tissue was analyzed for total mercury and selenium at the State Environmental Health Lab following a Quality Assurance Project Plan (Gerlach et al. 2002).
2) Molar ratios of Se:Hg and health benefit values:

$$HBV_{Se} = ((Se - Hg)/Se) \times (Se + Hg))$$

were determined (Kaneko & Ralston 2007; Ralston & Raymond 2015)
3) Means and variation were compared by species and location
4) Age was determined by otolith annuli

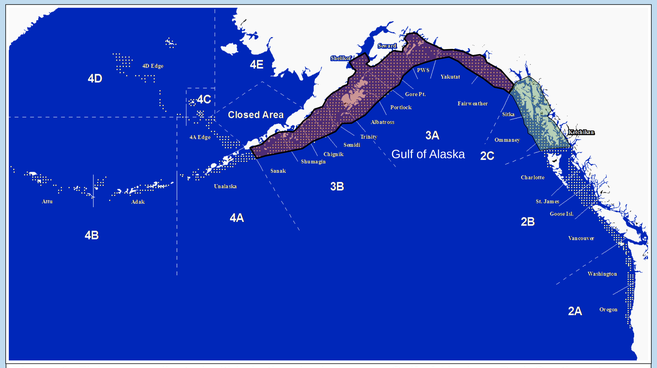

Figure 1: Fish were collected within in the shaded areas. Gulf of Alaska = Red; Southeast = Green.

Map source: IPHC, http://www.iphc.int/research/surveys.html

Results:

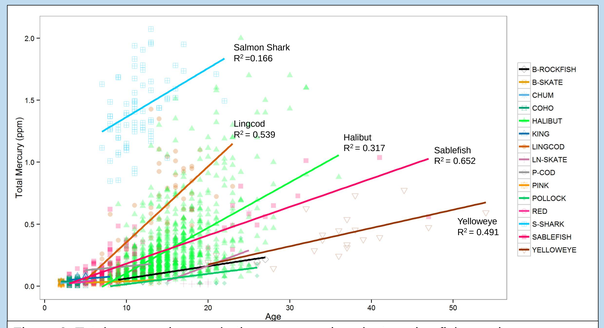

Figure 2: Total mercury in muscle tissue vs. age in select marine fish species.

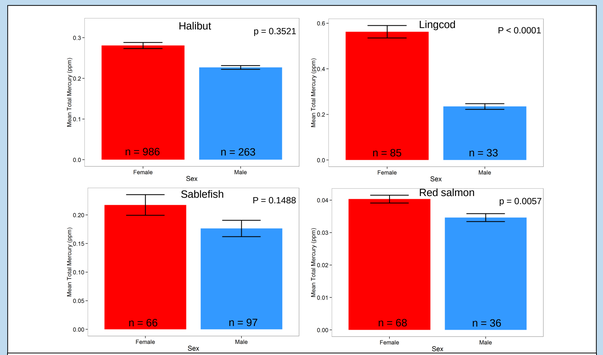

Figure 3: Total mercury in muscle tissue by sex in select species from GOA and SE.

Table 1: Length, age, selenium-mercury molar ratio, selenium health benefit value and correlation coefficients for fish in the Gulf of Alaska and Southeast Alaskan waters. Values are mean ± SD and Kendall's rank correlation coefficient (Tau)

Common name *Scientific name*	n	Length	Age	Se:Hg Mean ± SD	HBV_{Se} Mean ± SD	Se:Hg Corr w/ Length	Se:Hg Corr w/ Age	Se:Hg Corr w/ Mercury
Gulf of Alaska						tau	tau	tau
Big Skate *Raja binoculata*	30	128.55 ± 25.2	8.10 ± 3.0	54.49 ± 67.67	6.72 ± 3.51	-0.29	-0.06	-0.89
Black Rockfish *Sebastes melanops*	46	52.02 ± 5.5	14.52 ± 4.9	17.44 ± 13.04	6.56 ± 1.45	-0.38	-0.61	-0.84
Halibut *Hippoglossus stenolepis*	1061	107.96 ± 22.2	15.24 ± 4.3	7.06 ± 7.48	4.18 ± 3.05	-0.32	-0.46	-0.70
Lingcod *Ophiodon elongatus*	144	105.12 ± 15.1	13.01 ± 4.4	3.93 ± 4.20	3.02 ± 2.18	-0.55	-0.53	-0.85
Longnose Skate *Raja Rhina*	30	117.03 ± 10.4	18.80 ± 2.7	15.81 ± 20.71	3.78 ± 2.72	-0.10	-0.05	-0.87
Red salmon *Oncorhynchus nerka*	55	57.76 ± 6.2	4.98 ± 0.8	15.28 ± 5.73	2.90 ± 0.61	-0.27	-0.35	-0.69
Sablefish *Anoplopoma fimbria*	117	61.98 ± 7.5	7.62 ± 3.2	9.56 ± 9.40	2.52 ± 1.33	-0.29	-0.28	-0.76
Salmon Shark *Lamna ditropis*	109	223.79 ± 15	11.55 ± 3	0.62 ± 0.18	-8.27 ± 5.56	-0.10	-0.05	-0.87
Walleye Pollock *Theragra chalcogramma*	34	52.33 ± 7.3	NA	3.63 ± 1.60	1.94 ± 0.56	-0.16	-0.07	-0.73
Yelloweye *Sebastes ruberrimus*	52	61.74 ± 8.2	32.81 ± 9.1	4.11 ± 2.74	5.96 ± 1.68	-0.46	-0.45	-0.73
Southeast Alaska								
Pacific Cod *Gadus macrocephalus*	25	56.20 ± 4.49	10.00 ± 3.2	3.36 ± 0.78	2.36 ± 0.34	-0.74	-0.40	-0.40
Chum Salmon *Oncorhynchus keta*	121	64.91 ± 4.49	4.02 ± 0.8	18.07 ± 4.48	3.28 ± 0.46	-0.09	-0.30	-0.63
Coho Salmon *Oncorhynchus kisutch*	286	63.82 ± 6.82	3.44 ± 0.6	53.56 ± 153.4	4.69 ± 4.80	-0.01	0.06	-0.56
Halibut *Hippoglossus stenolepis*	359	112.55 ± 21.18	13.97 ± 3.86	5.53 ± 6.02	3.63 ± 3.18	-0.29	-0.47	-0.77
Pink Salmon *Oncorhynchus gorbuscha*	84	52.06 ± 4.13	2.00 ± 0	22.90 ± 12.86	2.78 ± 1.00	0.27	NA	-0.52
King Salmon *Oncorhhmchus tswatschi*	80	75.64 ± 6.96	4.94 ± 0.9	11.84 ± 4.92	3.08 ± 0.87	0.12	-0.12	-0.53
Red Salmon *Oncorhynchus nerka*	63	53.33 ± 8.42	5.11 ± 0.8	34.90 ± 81.67	4.41 ± 4.04	0.07	-0.22	-0.55
Sablefish *Anoplopoma fimbria*	69	64.88 ± 7.99	12.40 ± 8.7	3.38 ± 2.94	1.65 ± 1.93	-0.08	-0.44	-0.76

Table 2: Comparison between areas of fish collection. The differences between the GOA and SE fish molar ratio of selenium to mercury and the selenium health benefit values were tested using a Wilcoxon rank sum test. Range of mercury tissue concentration from both areas is also provided.

			Total Hg Range (ppm)	
	Se:Hg	HBV_{Se}	GOA	SE
Halibut	<0.0001	0.009	0.02 - 2.0	0.04 - 1.6
Sablefish	<0.0001	<0.0001	0.008 - 1.2	0.03 - 1.0
Red salmon	0.0009	0.0001	0.02 - 0.08	0.01 - 0.06

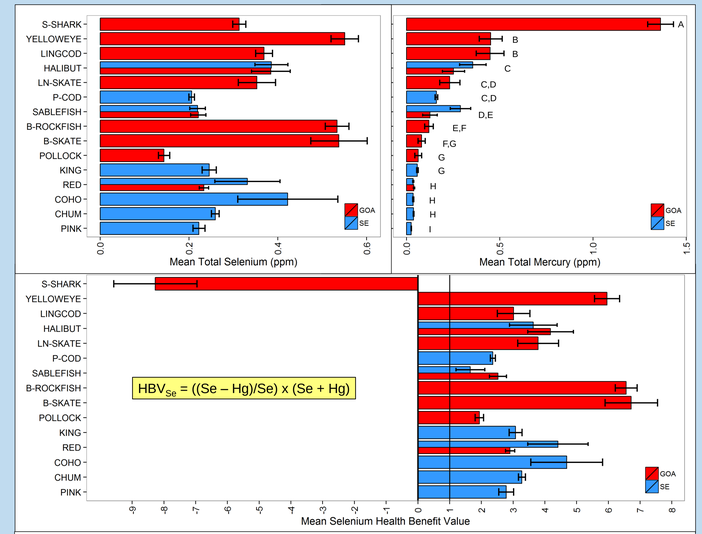

Figure 4: Mean values for selenium, total mercury and selenium health benefit values for select species in the Gulf of Alaska and Southeast Alaska. Different letters indicate significant differences in mercury levels between species (nonparametric Tukey multiple contrast p<0.05).

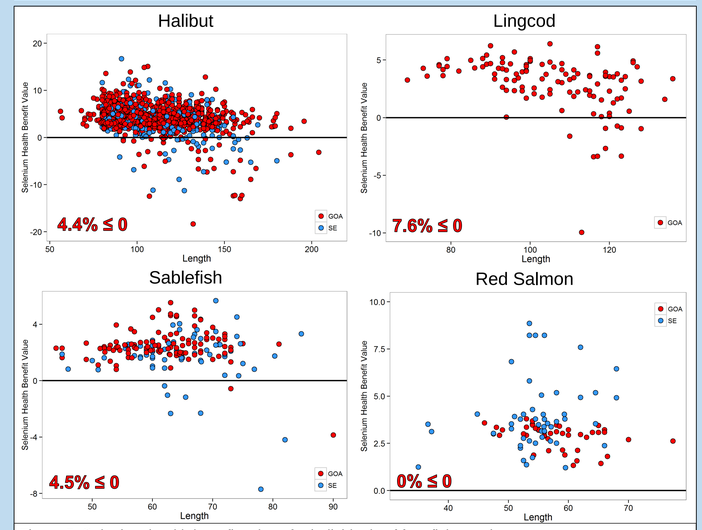

Figure 5: Selenium health benefit values for individuals of four fish species

Discussion:

- The FDA Recommended Daily Allowance for Se is 55 µg per day for adults
- A 100 g (3.5 oz) serving of Alaskan halibut provides 40±0.18 µg of Se (range = 7-260 µg)
- Se:Hg is negatively correlated with age and/or length
- Se:Hg varies within and between species and location
- Mean HBV_{Se} has a positive value for all commercially important species analyzed

Conclusions:

- Mercury concentrations in fish varies and is correlated with age and location and a majority of fish caught in Alaskan waters present low risk of mercury exposure
- HBV_{Se} varies within and between species but most Alaskan fish have a surplus of selenium which could provide some protection from mercury exposure
- Human fish consumption guidelines and biological modeling of mercury dynamics in the marine environment should include Se availability when making recommendations or drawing conclusions about impacts of mercury toxicity

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