Comprehensive assessment for controlling factor of total Hg level in skipjack tuna from Western North Pacific Ocean

Takaaki Itai, – Department of Earth and Planetary Science, The University of Tokyo, Japan, itai@eps.s.u-tokyo.ac.jp

Toshiki Kamei and Shinsuke Tanabe, – Center for Marine Environmental Studies, Ehime University, Japan

Background

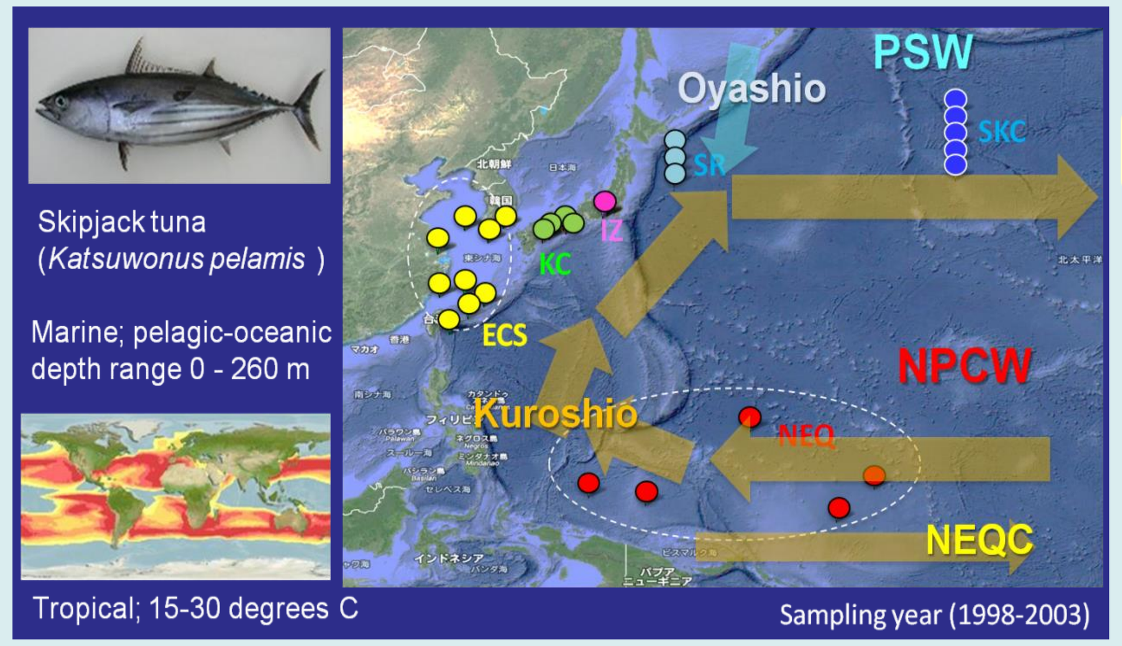
- Migratory pelagic marine species such as tuna are particularly significant source of MeHg to human (Sunderland, 2007; Yasutake et al., 2003).
- Even among the same species, considerable geographical variation have been reported (Hisamichi et al., 2010; Sunderland, 2007).
- Although age/size dependent increase of Hg has commonly observed, this trend can not be explained solely by bioenergetic process (Trudel & Rasmussen, 2006). To assess diet composition is critical point for mass balance modelling (Ferriss & Essington, 2014).
- In this study, we discuss about controlling factor of THg level in skipjack tuna considering size, trophic position, regional variation, and stable isotope signatures.

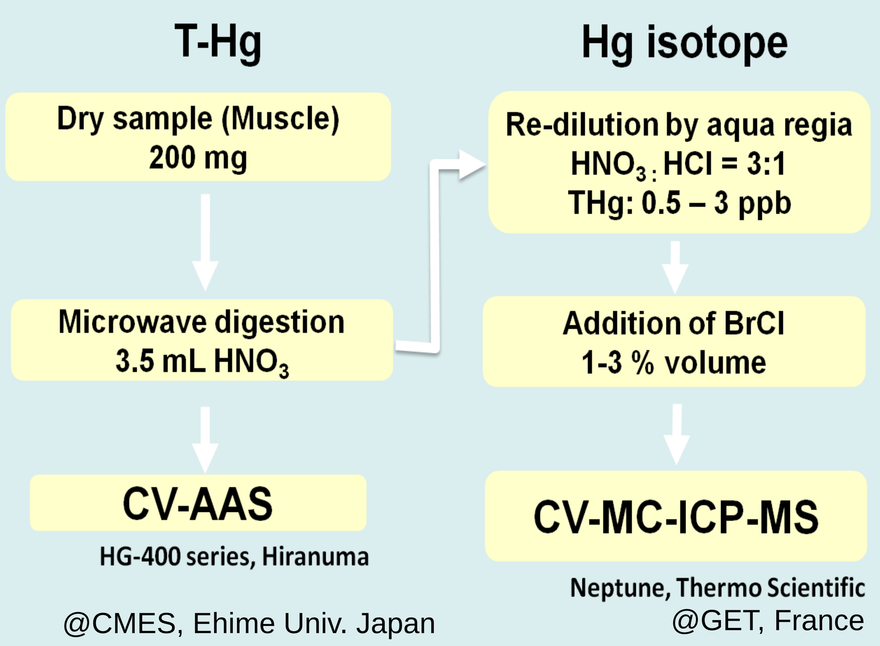
Conclusions

PSW (Polar Subarctic Water): Small size, low THg, high Δ^{199}Hg (foraging diet from shallower water).
Kuroshio: Large size, high THg, low Δ^{199}Hg (foraging diet from deeper water).
NEQ (Near Equator): Large size, low THg, intermediate Δ^{199}Hg .

Implications: Variation of Δ^{199}Hg possibly the function of foraging depth. Accepting this assumption, body size dependent increase of THg is attributed to the foraging from deep water having higher MeHg concentration. Further study for depth vs isotope signature will be important.

Materials and Methods





Accuracy of measurements were confirmed by measurement of ERM-CE464 (n=8; IRMM, Belgium), DOLT-4 (n=20; NRC, Canada) and oyster tissue (n=35, SRM 1566b, NIST, USA), with the average recovery being 103, 108, and 110%, respectively. The δ^{202}Hg of overall measurements of UM-Almaden, ETH-Fluka, and ERM-CE464 were -0.57 ± 0.12‰ (n=30), -1.44±0.24‰ (n=46), and 0.59 ± 0.11‰ (n=8), respectively. The Δ^{199}Hg of ERM-CE464 was 2.38±0.02‰ .

Results & Discussion

Regional variation

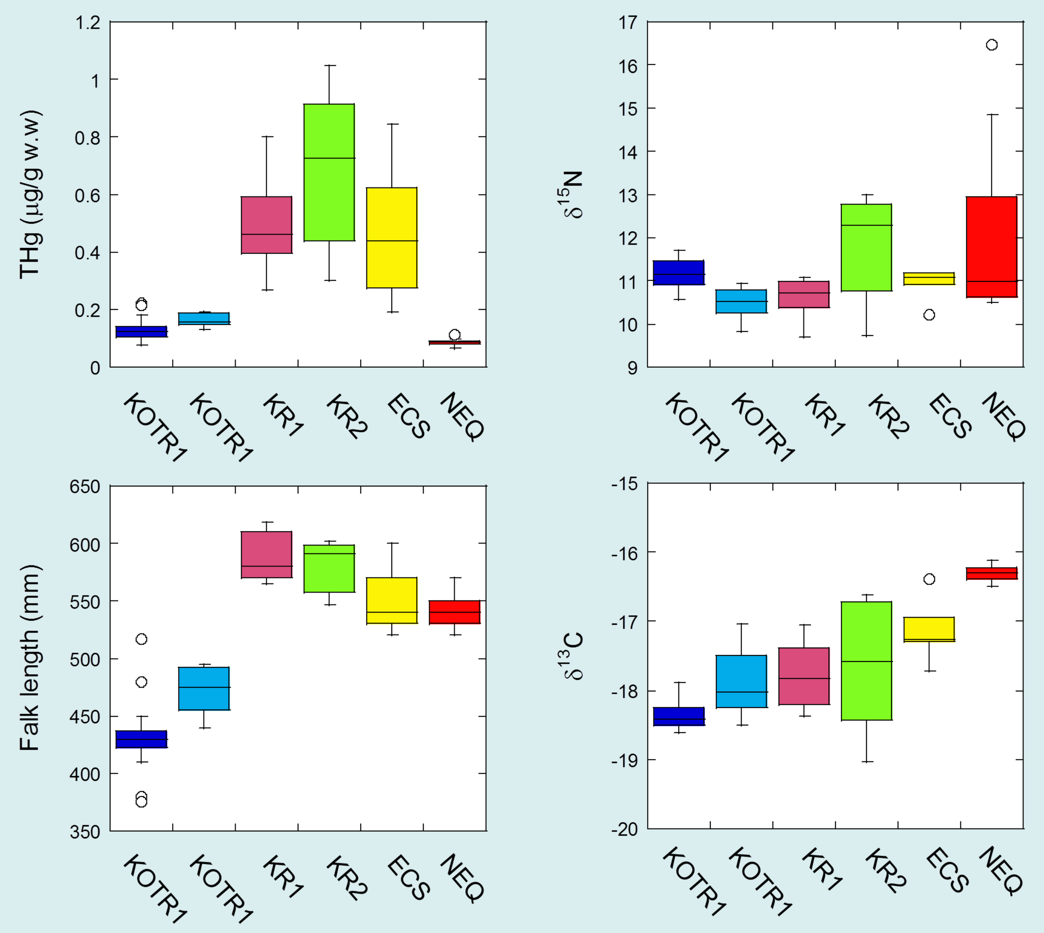


Fig. 1 Regional variation of (a) THg, (b) falk length, (c) δ^{15}N and (d) δ^{13}C.

Body size dependence

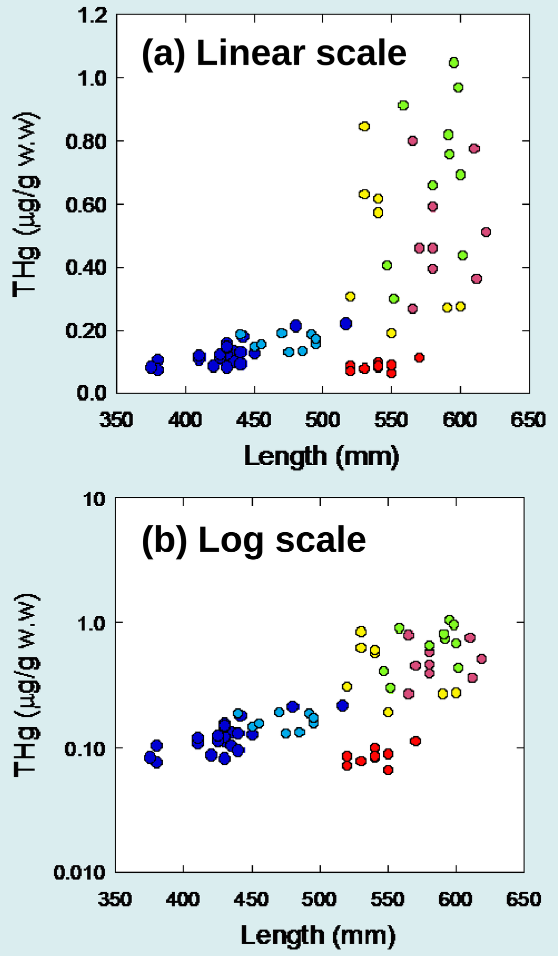


Fig. 2 Relationship between THg and falk length. (a) is linear and (b) is log scales.

THg(μg/g-wet)]
= 0.0251 × [body length (cm)]-0.971
R=0.6568, p<0.001

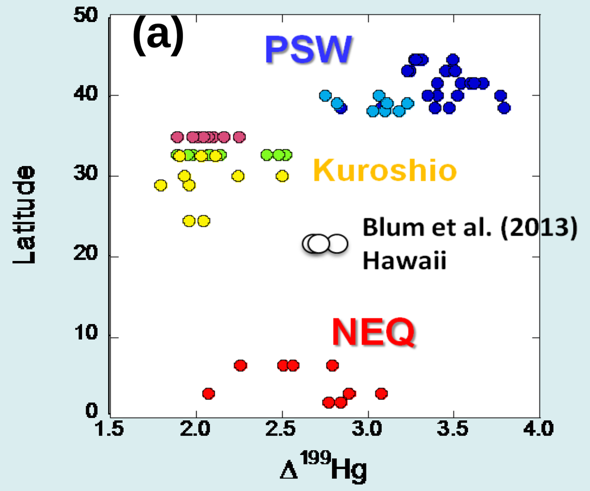
If the bioenergetics factors are the essence of the body size dependence, proper normalization is needed to consider the factors affecting THg other than size. However, the separate correlation plots for 6 region (Table 1) indicated that only KOTR1 showed significant correlation (p < 0.001, R = 0.7833), suggesting that body size is, at least in same region, not the primarily factor controlling THg.

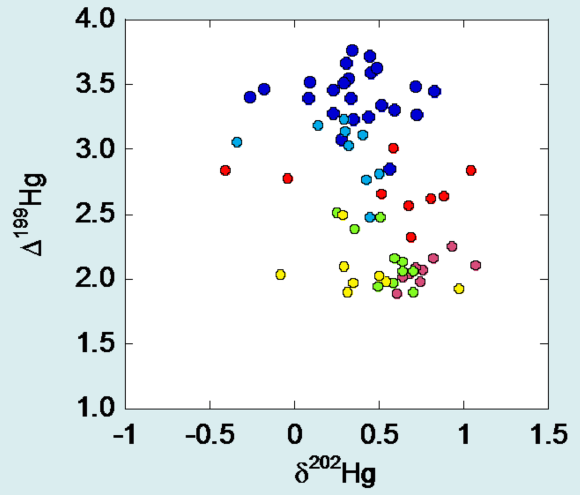
Correlation among variables

Table 1. The pearson's correlation coefficient and statistical significance of stepwise linear-regression analyses. The bold faces indicate p value <0.05. THg_{corr} represents normalized THg by body length.

	Body length vs.					δ^{15}N vs.		δ^{13C} vs.		δ^{202}Hg vs.		Δ^{199}Hg vs.	
	THg	δ^{15}N	δ^{13}C	δ^{202}Hg	Δ^{199}Hg	THg	δTHg_{corr}	THg	THg_{corr}	THg	THg_{corr}	THg	THg_{corr}
Overall													
n	68	58	58	68	58	58	58	58	58	68	68	68	68
R	**0.6568**	0.1508	0.4821	0.3796	**-0.9053**	0.1190	0.0354	0.0680	-0.2227	0.3204	0.0415	**-0.7514**	-0.2313
p	**0.0076**	0.6314	0.0873	0.1990	**<0.0001**	0.7060	0.9113	0.8301	0.4731	0.2887	0.8959	**0.0006**	0.4549
KOTR1													
n	23	21	21	23	23	21	21	23	23	23	23	23	23
R	**0.7833**	0.1194	-0.5408	0.3592	**-0.5899**	0.0978	0.0299	-0.2180	0.4154	0.1464	-0.3031	**-0.5898**	0.0868
p	**0.0007**	0.7078	0.0563	0.2371	**0.0311**	0.7593	0.9256	0.4876	0.1634	0.6446	0.3260	**0.0312**	0.7855
KOTR2													
n	9	8	8	9	9	8	8	8	8	9	9	9	9
R	-0.0508	-0.1221	0.1419	0.0854	**-0.6404**	**0.6623**	0.5943	**-0.7305**	**-0.6760**	**0.6076**	0.2588	-0.1164	0.4022
p	0.8768	0.7106	0.6663	0.7943	**0.0336**	**0.0314**	0.0581	**0.0148**	**0.0273**	**0.0461**	0.4248	0.7219	0.2074
KR1													
n	9	7	7	9	9	7	7	7	7	9	9	9	9
R	0.0926	0.2563	0.4257	0.0563	-0.2170	0.5449	0.3943	**0.8855**	**0.6913**	-0.5226	-0.4072	**-0.6842**	-0.4746
p	0.7772	0.4401	0.1970	0.8635	0.5048	0.0950	0.2329	**0.0018**	**0.0292**	0.0938	0.2014	**0.0209**	0.1320
KR2													
n	10	9	9	10	10	9	9	9	9	10	10	10	10
R	0.4650	0.2525	-0.2929	**0.6059**	-0.4022	0.5702	0.5397	-0.3587	-0.2147	**0.8164**	**0.6700**	**-0.6581**	-0.5525
p	0.1353	0.4364	0.3649	**0.0426**	0.2022	0.0642	0.0822	0.2637	0.5093	**0.0021**	**0.0214**	**0.0245**	0.0694
ECS													
n	8	6	6	8	8	6	6	6	6	8	8	8	8
R	-0.5428	0.0316	**0.7188**	-0.5708	0.0526	-0.0143	-0.0531	-0.4340	-0.4988	0.3717	0.4228	-0.5949	-0.5254
p	0.0870	0.9252	**0.0308**	0.0703	0.8732	0.9661	0.8747	0.2023	0.1429	0.2525	0.1906	0.0578	0.0987
NEQ													
n	9	7	7	9	7	7	7	7	7	9	9	9	9
R	0.5614	0.5745	**0.8205**	**-0.6313**	-0.0034	0.5959	N/A	0.1903	N/A	**-0.7605**	N/A	0.2316	N/A
p	0.0691	0.0772	**0.0062**	**0.0368**	0.9918	0.0659	N/A	0.5667	N/A	**0.0076**	N/A	0.4762	N/A

Mercury stable isotope





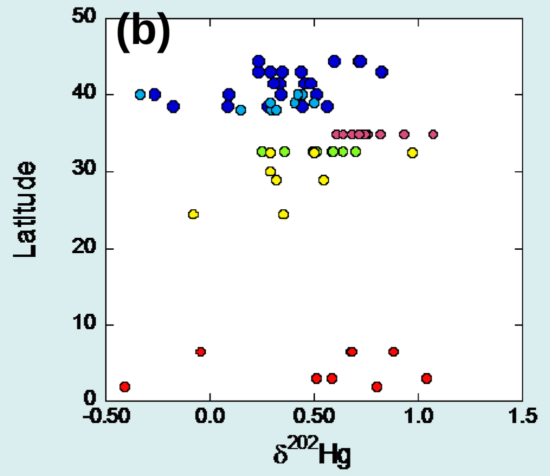
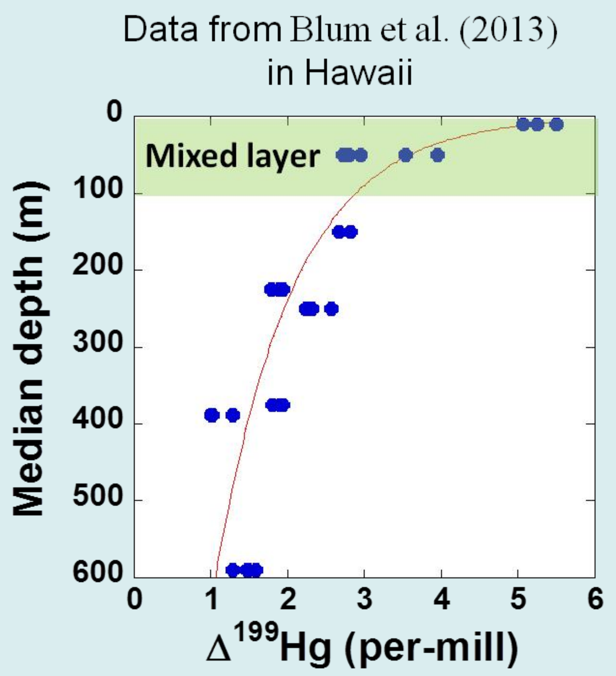
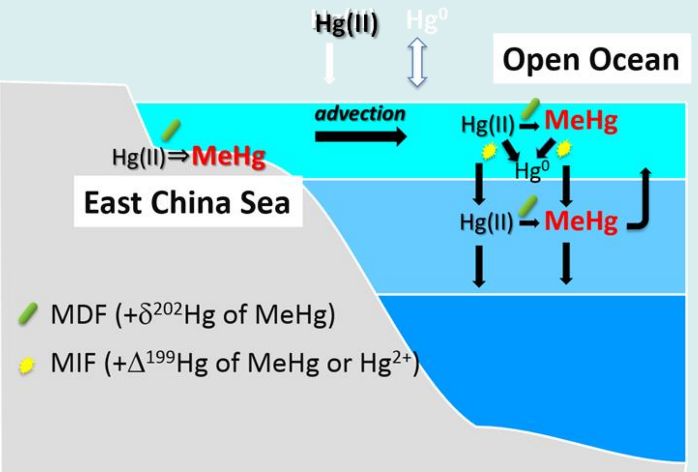


Fig. 3 Latitudinal change of (a) Δ^{199}Hg. and (b) δ^{202}Hg.
Fig. 4 Relationship between δ^{202}Hg and Δ^{199}Hg.

The δ^{202}Hg and Δ^{199}Hg of overall samples were ranged from -0.41 to 1.04‰, 1.90 to 3.77‰, respectively (Fig. 3). These variations are much larger than Blum et al. (2013), which measured same species in Hawaii, showing δ^{202}Hg and Δ^{199}Hg: 0.63 ± 0.08‰ and 2.71 ± 0.17‰, respectively (2SD, n = 3). This indicates isotope signal is variable depending on the region even among the same species.

Interpretation of MIF signature I





Assumption
MeHg is predominantly formed below mixed layer. Δ^{199}Hg value is controlled by mixing of residual MeHg, which formed in the mixed layer, and that formed below mixed layer.

Fig. 5 Proposed model for MIF vs. migration depth trend by Blum et al. (2013)

Interpretation of MIF signature II

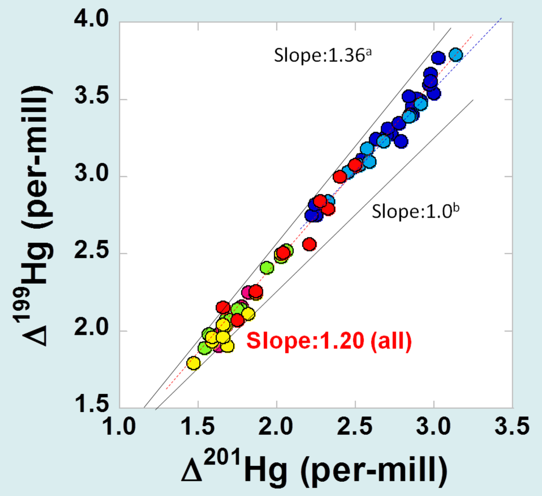


Fig. 6 Relationship between Δ^{199}Hg and Δ^{201}Hg.

[a] Bergquist and Blum (2007) MMHg photo-degradation experiment.
[b] Bergquist and Blum (2007) Hg^{II} photo-reduction experiment.

Overall slope being 1.20 is same to the other data of marine biota (e.g., Blum et al. 2013).

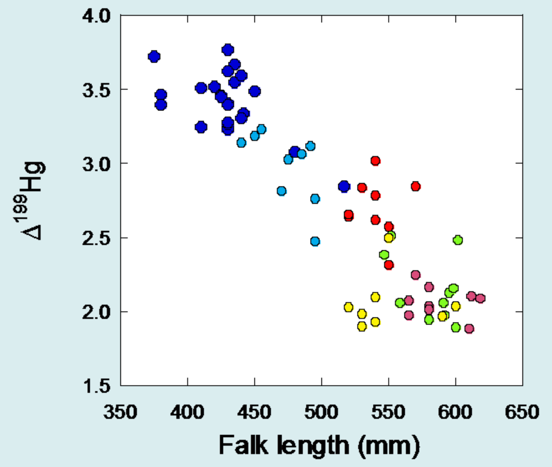


Fig. 7 Relationship between Δ^{199}Hg and falk length

Clear negative correlation
=> Smaller individuals (PSW) forage diet from shallower water, while bigger individuals (Kuroshio, NEQ) are from deeper water.
Increasing size increase thermal inertia and heat production via metabolism. (Barkley et al., 1978)

MIF signature vs THg

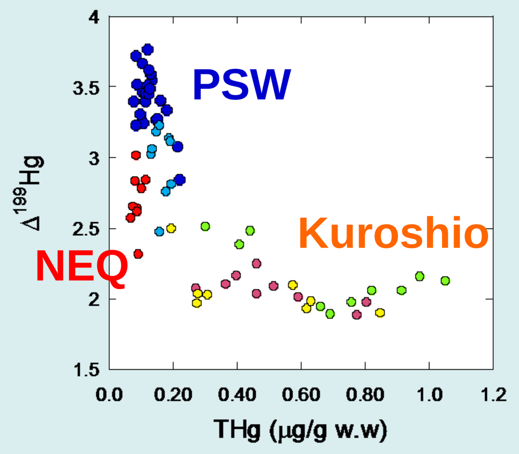


Fig. 8 Relationship between Δ^{199}Hg and THg.

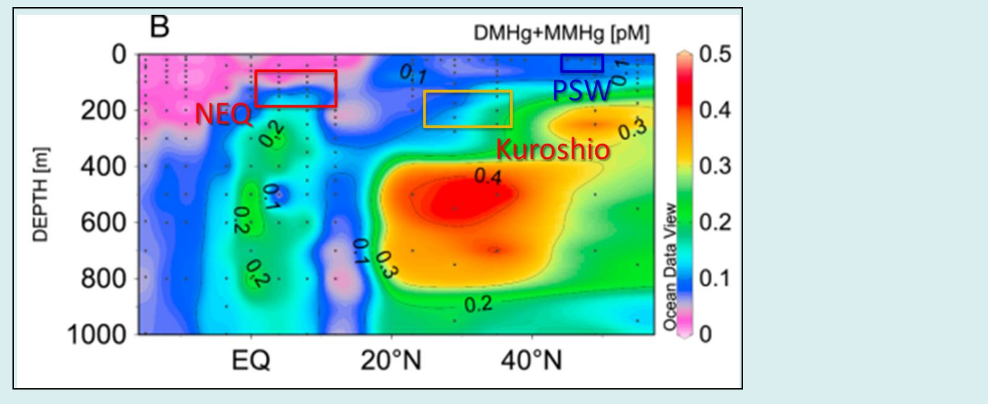


Fig. 9 Transect of Hg species along the CUVAR P16N section (150-175W) by Munson et al. (2015). Depth range was tentatively estimated by Δ^{199}Hg value and depth- Δ^{199}Hg by Blum et al. (2013).

PSW	Kuroshio	NEQ
High Δ^{199}Hg (shallow migration) Low THg	Low Δ^{199}Hg (deep migration) High THg	Intermediate Δ^{199}Hg Low THg (low MeHg background)

References
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