1.9 - Diving depth of elephant seals influences mercury bioaccumulation in the north Pacific Return to TOC

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Mercury in marine ecosystems is increasing (Sunderland et al. 2009), with an associated increase in risk for both humans and wildlife. Although mercury enters the environment via both natural and anthropogenic sources, the increased levels can be attributed primarily to human sources, such as coal-fired power plants (Streets et al. 2011). Mercury levels will continue to increase, even if anthropogenic emissions are halted, because of the time lag required for mercury to equilibrate between the atmosphere and the ocean (Sunderland and Mason 2007, Mason et al. 2012). Environmental mercury is of concern because it can cause neurological problems in vertebrates. The effects of mercury accumulation can be acute or sub-clinical (not visually detectable) over a wide range of concentrations and lengths of exposure (Das et al. 2003, Basu et al. 2009). Furthermore, mercury has no known beneficial role in organisms. Higher trophic level predators are generally at greatest risk of mercury contamination due to their propensity for biomagnification (Atwell et al. 1998), however, mercury bioaccumulation is poorly understood for predators in remote marine ecosystems.

Northern elephant seals (*Mirounga angustirostris*) are top marine predators in the northeast Pacific Ocean. They dive deeply and forage within the mesopelagic zone (200-1000 m depths). Elephant seals travel thousands of kilometers during their biannual migrations - moving between beach haul-outs and at-sea foraging areas (Fig. 19). Regional differences in mercury concentrations in surface-feeding (epipelagic zone) marine species have been observed in the north Pacific, but mercury concentrations in predators that use the deeper, mesopelagic food webs have not been well described. Deep-diving predators should encounter higher mercury concentrations as the biogeochemistry associated with these depths makes mercury more bioavailable in the mesopelagic than the epipelagic zone (Sunderland et al. 2009). For example, peak mercury concentrations within the water column were observed in the mesopelagic zone during a latitudinal transect study in the northeast Pacific Ocean (Laurier et al. 2004, Sunderland et al. 2009). Therefore, elephant seals are exposed to the region where the highest concentrations of mercury were measured (Robinson et al. 2012), making them particularly vulnerable to mercury accumulation. Additionally, elephant seals may be good indicators of regional mesopelagic contamination because satellite tracking has revealed that individual seals demonstrate strong regional fidelity during foraging migrations (Simmons 2008, Costa et al. 2012), but the species as a whole forages across an extensive portion of the northeast Pacific Ocean (Robinson et al. 2012).

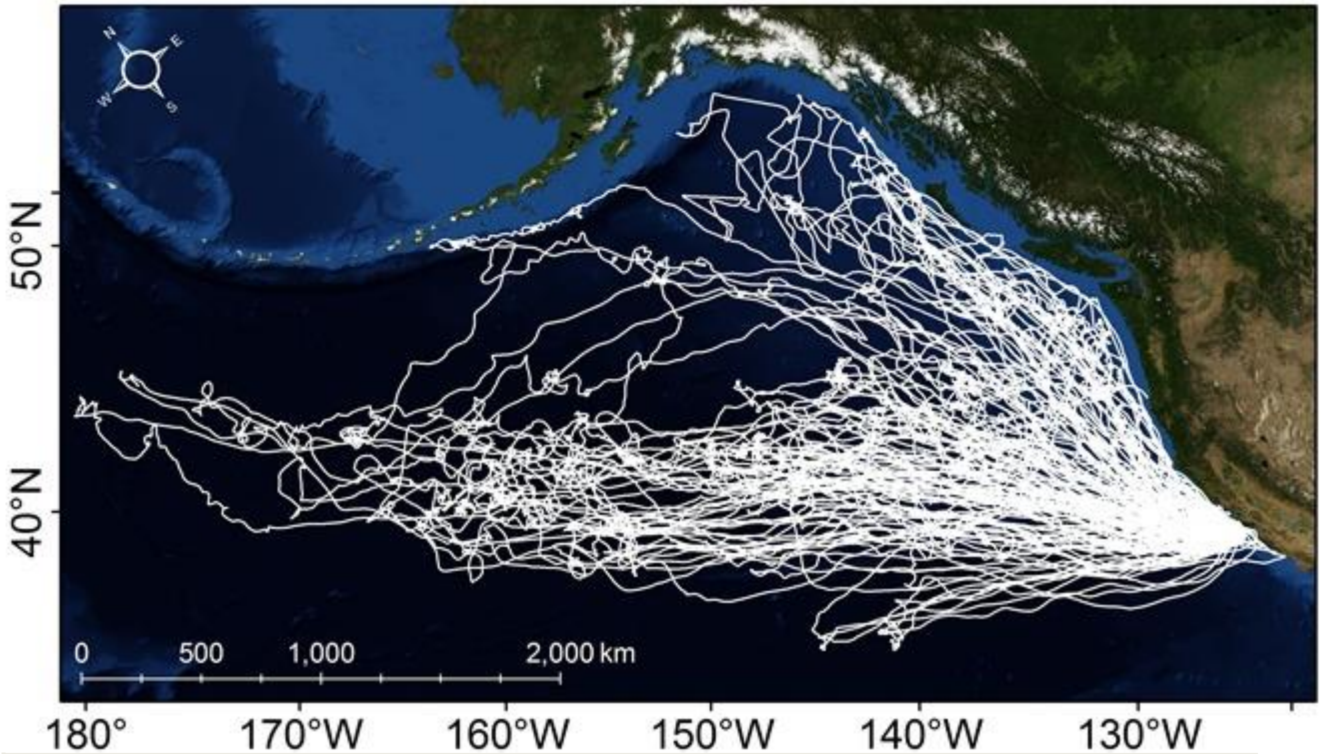

Figure 19. Satellite tracks of 75 northern elephant seal females that were sampled for mercury in blood and muscle. Satellite tags were deployed on seals at the Año Nuevo colony in California, USA, although foraging occurs across a wide range of the northeast Pacific Ocean.

We coupled animal behaviour, including movements and dive behaviour in the water column, with contaminant research to gain insight into mercury accumulation in predators from a relatively inaccessible marine ecosystem. Mesopelagic predators are, in general, difficult to sample due to the limitations of deep ocean research. However, elephant seals consistently travel back from their open-ocean foraging grounds, at which point they are accessible for sampling. Additionally, long-term demographic studies on the breeding colony at Año Nuevo State Reserve (California, USA) provided us with the opportunity to incorporate animal age and other demographic information that is typically unknown for free-ranging marine predators. The power of our study lies in the fact that we were able to overcome some of the pervasive challenges in contaminant research by being able to link animal behaviour and demographics directly with contaminant accumulation.

We deployed satellite tags and time-depth recorders on more than 70 known-age adult female elephant seals (Fig. 20) during 2010-2013, for either the two- (short) or six- (long) month foraging migration (Fig 21; Peterson et al. 2014). During the deployment and subsequent recovery procedures, we collected (non-lethally) blood and muscle samples.

Figure 20. Satellite tags and time depth recorders were deployed on adult female northern elephant seals for the duration of their foraging migrations (D. Costa; NMFS Permit 14636).

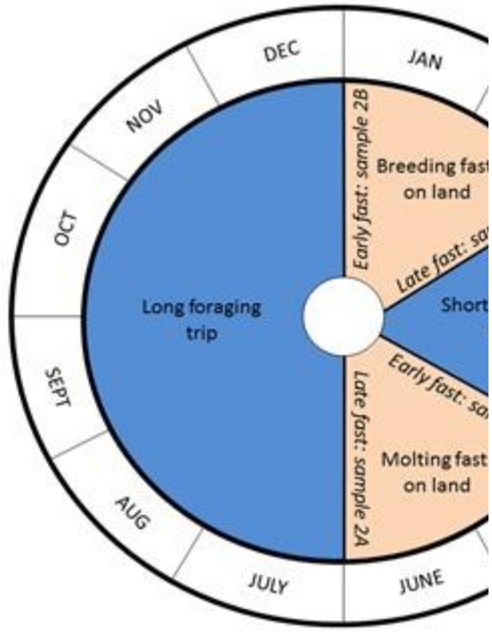

Figure 21. Blood and muscle samples were collected from adult female elephant seals for mercury analysis at the start and end (1A/1B and 2A/2B) of their biannual foraging trips, shown in blue. Seals were sampled 2010-2013 at the Año Nuevo colony in California, USA.

Our preliminary findings indicate that elephant seals have relatively high mercury concentrations compared with many marine predators, and suggest that other marine predators foraging in the mesopelagic may be at an increased risk for mercury bioaccumulation. The average mercury concentration in elephant seals was higher than those measured in their coastal and epipelagic-foraging northeast Pacific counterparts, including harbour seals (*Phoca vitulina*) (Brookens et al. 2007, McHuron et al. 2014) and California sea lions (*Zalophus californianus*) (unpublished data S. Peterson and L. McHuron). Furthermore, for comparison, mercury concentrations in elephant seals were more than eight times higher than those in yellowfin tuna (Ordiano-Flores et al. 2011), swordfish (Storelli et al. 2005), and bluefin tuna muscle (Storelli et al. 2005). Although no overt impairments have been observed in elephant seals that could be attributed to mercury contamination, sub-clinical effects may be present and currently undetected in the population.

To our knowledge, this is the first study to combine mercury concentrations in free-ranging, deep-diving marine mammals from the north Pacific with demographic and individual foraging behaviour information. We found that foraging ecology, including foraging location and diving depth, influenced mercury concentrations in adult female elephant seals. Although our results are preliminary, they indicate that predators foraging within the mesopelagic zone may be at greater risk of mercury accumulation than previously assumed. Further, our results provide insight into the potential for mercury bioaccumulation in more elusive and vulnerable species. Our findings align with previous ocean research on mercury in the water column and provide support for cross-disciplinary research and the integration of biogeochemistry and ecology.

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References

- Atwell, L., K. A. Hobson, and H. E. Welch. 1998. Biomagnification and bioaccumulation of mercury in an arctic marine food web: insights from stable nitrogen isotope analysis. *Canadian Journal of Fisheries and Aquatic Sciences* 55: 1114-1121.

- Basu, N., A. M. Scheuhammer, C. Sonne, R. J. Letcher, E. W. Born, and R. Dietz. 2009. Is dietary mercury of neurotoxicological concern to wild polar bears (*Ursus maritimus*)? *Environmental Toxicology and Chemistry* 28: 133-140.

- Brookens, T. J., J. T. Harvey, and T. M. O'Hara. 2007. Trace element concentrations in the Pacific harbor seal (*Phoca vitulina richardii*) in central and northern California. *Science of The Total Environment* 372: 676-692.

- Costa, D. P., G. A. Breed, and P. W. Robinson. 2012. New insights into pelagic migrations: implications for ecology and conservation. *Annual Review of Ecology, Evolution, and Systematics* 43: 73-96.

- Das, K., V. Debacker, S. Pillet, and J.-M. Bouquegneau. 2003. Heavy metals in marine mammals. Pages 135-167 *in* J. G. Vos, G. D. Bossart, M. Fournier, and T. J. O'Shea, editors. Toxicology of marine mammals. Taylor & Francis, New York.

- Laurier, F. J. G., R. P. Mason, G. A. Gill, and L. Whalin. 2004. Mercury distributions in the North Pacific Ocean - 20 years of observations.*Marine Chemistry* 90: 3-19.

- Mason, R. P., A. L. Choi, W. F. Fitzgerald, C. R. Hammerschmidt, C. H. Lamborg, A. L. Soerensen, and E. M. Sunderland. 2012. Mercury biogeochemical cycling in the ocean and policy implications. *Environmental Research* 119: 101-117.

- McHuron, E. A., J. T. Harvey, J. M. Castellini, C. A. Stricker, and T. M. O’Hara. 2014. Selenium and mercury concentrations in harbor seals (*Phoca vitulina*) from central California: Health implications in an urbanized estuary. *Marine Pollution Bulletin* 3(1): 48-57.

- Ordiano-Flores, A., F. Galván-Magaña, and R. Rosiles-Martínez. 2011. Bioaccumulation of mercury in muscle tissue of yellowfin tuna, *Thunnus albacares*, of the Eastern Pacific Ocean. *Biological Trace Element Research* 144: 606-620.

- Peterson, S. H., J. L. Hassrick, A. Lafontaine, J.-P. Thomé, D. E. Crocker, C. Debier, and D. P. Costa. 2014. Effects of Age, Adipose Percent, and Reproduction on PCB Concentrations and Profiles in an Extreme Fasting North Pacific Marine Mammal. *PLoS ONE* 9: e96191.

- Robinson, P. W., D. P. Costa, D. E. Crocker, J. P. Gallo-Reynoso, C. D. Champagne, M. A. Fowler, C. Goetsch, K. T. Goetz, J. L. Hassrick, L. A. Hückstädt, C. E. Kuhn, J. L. Maresh, S. M. Maxwell, B. I. McDonald, S. H. Peterson, S. E. Simmons, N. M. Teutschel, S. Villegas-Amtmann, and K. Yoda. 2012. Foraging behavior and success of a mesopelagic predator in the northeast Pacific Ocean: Insights from a data rich species, the northern elephant seal. *PLoS ONE* 7: e36728.

- Simmons, S. E. 2008. Environmental and individual effects on the foraging success of an apex predator, the northern elephant seal (*Mirounga angustirostris*). University of California Santa Cruz, Santa Cruz.

- Storelli, M. M., R. Giacominelli-Stuffler, A. Storelli, and G. O. Marcotrigiano. 2005. Accumulation of mercury, cadmium, lead and arsenic in swordfish and bluefin tuna from the Mediterranean Sea: A comparative study. *Marine Pollution Bulletin* 50: 1004-1007.

- Streets, D. G., M. K. Devane, Z. Lu, T. C. Bond, E. M. Sunderland, and D. J. Jacob. 2011. All-time releases of mercury to the atmosphere from human activities. *Environmental Science & Technology* 45: 10485-10491.

- Sunderland, E. M., D. P. Krabbenhoft, J. W. Moreau, S. A. Strode, and W. M. Landing. 2009. Mercury sources, distribution, and bioavailability in the North Pacific Ocean: Insights from data and models. *Global Biogeochemical Cycles* 23(2), DOI: 10.1029/2008GB003425.

- Sunderland, E. M. and R. P. Mason. 2007. Human impacts on open ocean mercury concentrations. *Global Biogeochem. Cycles* 21 (4), DOI: 10.1029/2006GB002876.