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Pollution 2020 - Cetacean contaminant mapping tool

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Abstract

A mapping tool to display published data on the concentration of persistent organic pollutants and mercury in cetacean tissues, on a global scale, has been created. The purpose is to allow researchers to quickly view, and explore visually, trends in the concentrations of commonly monitored contaminants over time. The tool will be made available online through the IWC website.

Introduction

An objective of Phase III of the IWC Pollution 2020 Initiative was to produce a mapping tool which could be used to display and explore the global trends in the concentrations of contaminants measured in various cetacean species over time. Since the persistent organic pollutants (POPs) and heavy metals were first identified in cetacean tissues in the 1970s, many studies have been published reporting their concentrations in various tissues. This means there are almost four decades of data which may be used to determine how pollutant levels are changing in various species across the ocean basins of the world. The vast majority of the data collected relates to concentrations of the lipophilic POPs that have been measured in blubber samples collected from dead animals, although data from levels measured in biopsy samples from live animals are also included. In addition, recent interest by the Commission in concentrations of mercury prompted the inclusion of data on this heavy metal in liver samples. Whilst concentrations in muscle samples have also been monitored, the most common tissue and therefore the one with the largest dataset, is liver samples from stranded animals.

However, there are various caveats which need to be considered when viewing and making inferences from these data and the significance of any trends needs to be interpreted with some caution. Firstly, the concentrations in adult females can change with their age and reproductive history, as a large proportion of their POP burden is offloaded to the calf during gestation and lactation. Where individuals were in their reproductive cycle when they were sampled will thus influence the level of POPs measured. In this mapping project we have therefore restricted the POP data to concentrations reported in adult males only, since they are more representative at a population level. Unfortunately, it was not possible to account for the age of the animals which may also introduce some bias into the trends as the concentration in males may continue to increase with age. Secondly, concentrations will vary in relation to condition and blubber thickness as POP contaminant levels can increase in concentration when animals are in poorer condition with lower blubber stores. Thirdly, the analytical methods used to determine the POPs and the number of individual chemical congeners that can be identified has changed considerably over the last forty years and this may influence the total POP concentrations reported in the various studies across the time series. To minimise the impact of this effect, the map only includes levels of total PCBs and total DDTs on a lipid weight basis, rather than displaying data on a congener-specific basis. However, the caveat still remains that earlier reported levels may be misleading due to higher

measurement error and that total levels in recent years will include additional congeners that were not technically possible to measure in earlier years.

Following discussions at SC67B, the Commission's interest in the impact of mercury on cetaceans and the signing of the Minimata Convention by many countries (http://www.mercuryconvention.org/, an agreement which seeks to reduce mercury inputs into the environment), it was decided to include mercury concentrations in the mapping tool. This would be a useful means of tracking how levels have changed historically and provide a means of monitoring changes into the future. However, as with the POPs analytical method accuracy has improved over time and published reports are not always comparable because different tissues have been analysed (largely liver, muscle and skin) and reported on both wet and dry weight basis. For consistency, only liver concentrations on a dry weight basis have been included in the map.

Contaminant Data

A list of the references and sources for the contaminant data included in Version 1.1 of the Cetacean Contaminant Mapping Tool (CCMT) are listed in Appendix 1.1 for the POPs and Appendix 1.2 for mercury. The literature included were only those papers where either individual level data, from which median concentrations could be calculated, were reported or where median values were given for the adult males (for the POPs) within the sample set analysed. For the POPs lipid weight concentrations in blubber (both in dead and live biopsy sampled animals) were taken and for mercury dry weight in liver samples were included. For the POPs, currently only those species for which a reasonable amount of data is available were included, so that decadal changes could be visualised. However, following the review of mercury for SC67B more data were collated during that activity so these have been included in the current dataset. Data were entered consistently into an Excel spreadsheet which was then accessed by the CCMT script code.

Cetacean Contaminant Mapping Tool

The programme R was used to code the mapping tool which then used the package *Shiny* to produce a map showing the trends in the data. This produces a web-interface that can be manipulated to some extent by the user. Various options are available to show subsets of the data and the map can be zoomed so that users can drill down into the individual data being displayed. A screen shot of the map is shown in Figure 1.

Each circle shows the number of datasets in the database for that region (for example, in Figure 1 this is 13 for the Gulf of Mexico etc.). If the option to select all the data for a given region is chosen, then the plot in the bottom right shows the median and range of the data by each decade.

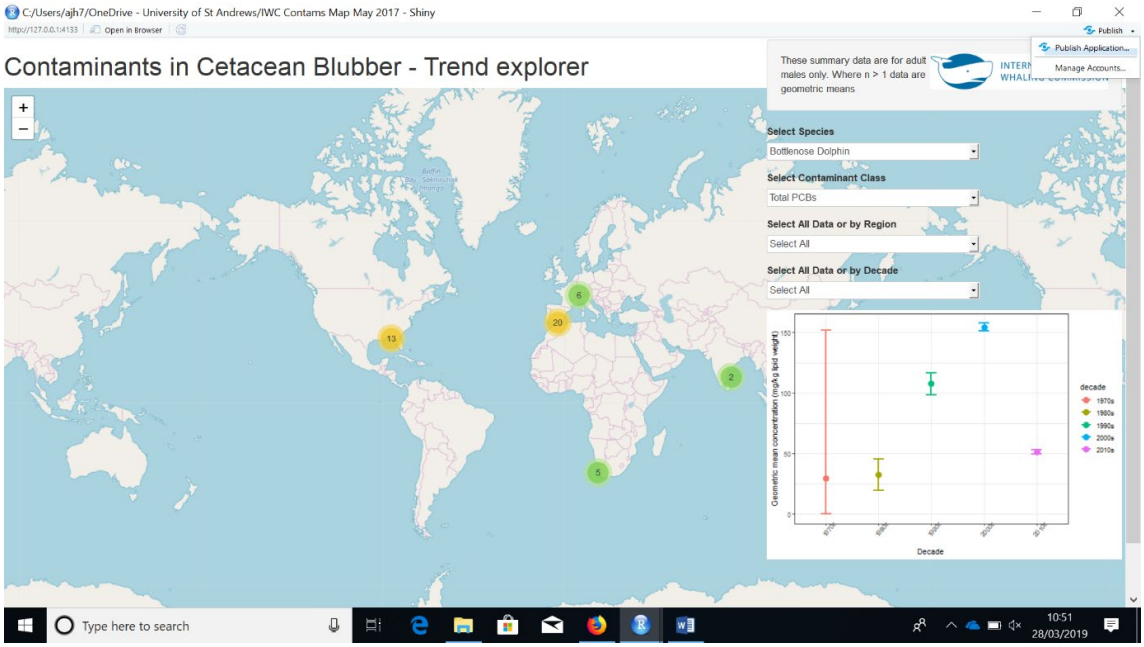

Figure 1. Screen shot of the contaminants mapping tool showing the data for total PCBs in bottlenose dolphins as the selected dataset to be displayed.

If the user then clicks on the circle the map zooms to that region to show where within the area the individual records were obtained. At the lowest level the user can then see the median concentrations and the number of datapoints for that area which were then combined into the figure at the bottom left (Figure 2). If there is insufficient data for the script to calculate a trend (with a geometric mean and standard deviations) for a species, region or decade, then the plot reverts to a bubble plot showing the individual data with the size of the points being related to the number of animals contributing to the dataset. Unfortunately, in most cases the raw data are not published so it has not been possible to delve deeper into the uncertainty and variability in some of the datasets.

If the user than choses a certain decade then the plot in the bottom right changes to a bubble plot. The x axis is then the particular years within that decade for which data were available. (for example, in Figure 3 the data for bottlenose dolphins in the Gulf of Mexico in the 2010s is shown). If there are no data for a given year a red error message will appear.

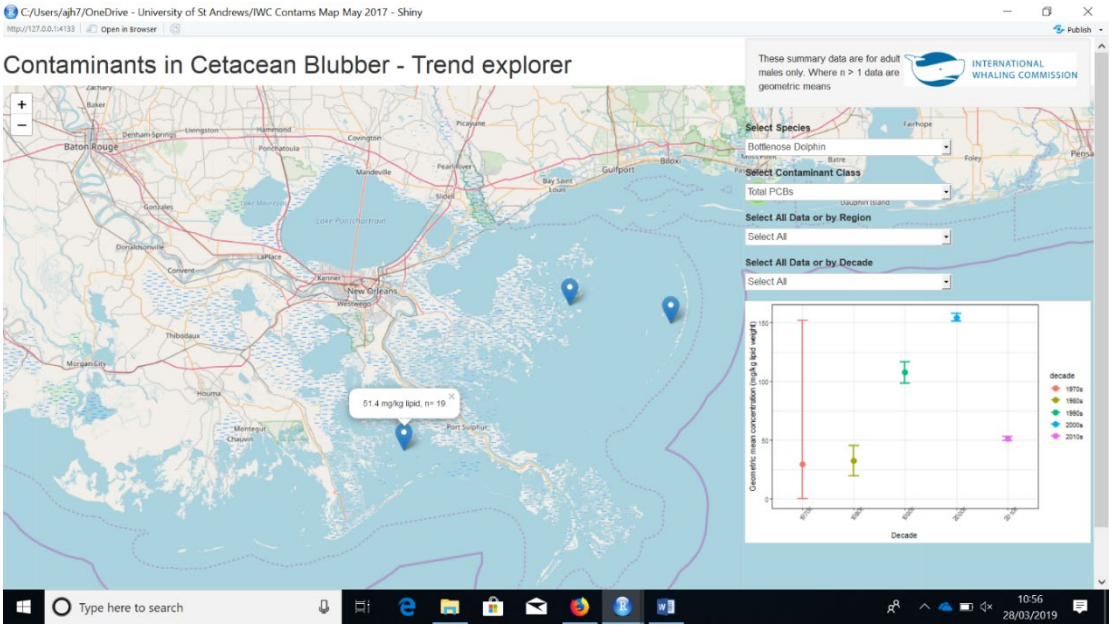

Figure 2. Zoom to individual dataset level. When points are clicked, the individual dataset for that location with the median concentration and the number of individuals, are shown.

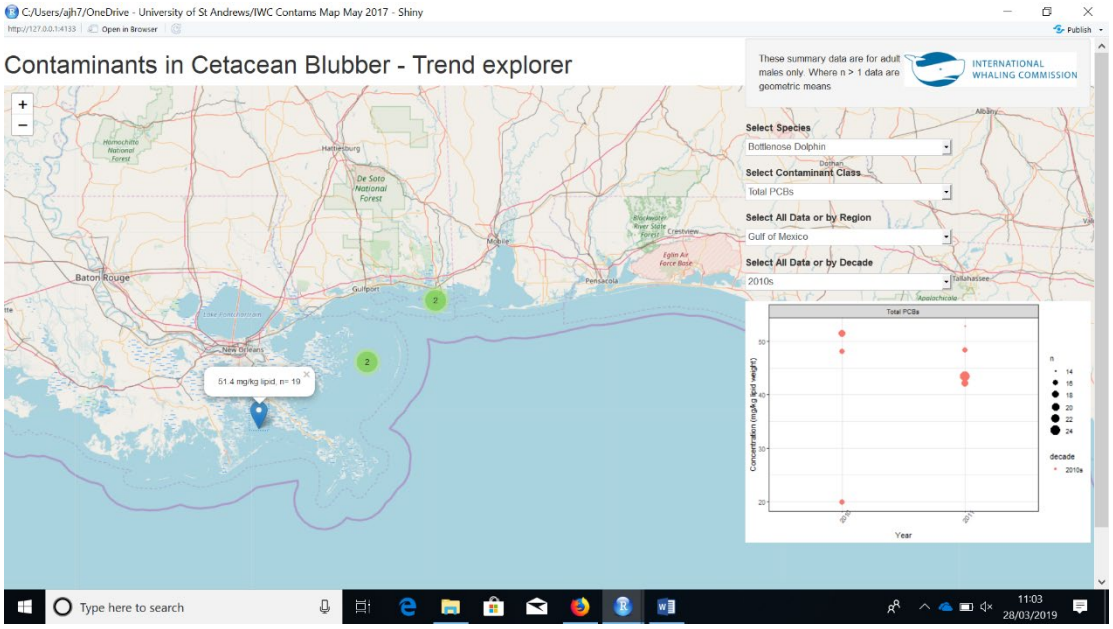

Figure 3. Zoom to individual dataset level. Here the user has selected 2010s so the plot shows the data for the two years for which the data were available.

The code for this tool will be made freely available through the Sea Mammal Research Unit, University of St Andrews website and will be linked to the International Whaling Commission webpage on pollution. The spreadsheet which stores the data can be updated as required, and instructions on how to ensure the data are entered correctly will be made available once the Subcommittee has decided on how this would be carried out.

Conclusion

This tool represents a unique resource for the cetacean research community to access contaminant trend data and will also provide a useful teaching resource. It is our hope that this endeavour will continue to be updated and used in future, beyond the life of the Pollution 2020 Initiative.

Appendices

References for data currently included in CCMT

Appendix 1.1

References for data on POPs

Anderson, S.H. and Rebsdorff A. (1976). Polychlorinated hydrocarbons and heavy metals in harbour porpoise (*Phocoena phocoena*) and whitebeaked dolphin (*Lagenorhynchus albirostris*) from Danish Waters. *Aquat. Mamm*. 4(1), 14-20.

Balmer, B. C., L. H. Schwacke, R. S. Wells, R. C. George, J. Hoguet, J. R. Kucklick, S. M. Lane, A. Martinez, W. A. McLellan, P. E. Rosel, T. K. Rowles, K. Sparks, T. Speakman, E. S. Zolman, and D. A. Pabst. (2011). Relationship between persistent organic pollutants (POPs) and ranging patterns in common bottlenose dolphins (*Tursiops truncatus*) from coastal Georgia, USA. *Sci Total Environ* 409:2094-2101.

Balmer, B. C., G. M. Ylitalo, L. E. McGeorge, K. A. Baugh, D. Boyd, K. D. Mullin, P. E. Rosel, C. Sinclair, R. S. Wells, E. S. Zolman, and L. H. Schwacke. (2015). Persistent organic pollutants (POPs) in blubber of common bottlenose dolphins (Tursiops truncatus) along the northern Gulf of Mexico coast, USA. *Sci Total Environ* 527-528:306-312.

Beineke, A., U. Siebert, M. McLachlan, R. Bruhn, K. Thron, K. Failing, G. Muller, and W. Baumgartner. (2005a). Investigations of the potential influence of environmental contaminants on the thymus and spleen of harbor porpoises (*Phocoena phocoena*). *Environ Sci Technol* 39:3933-3938.

Beineke, A., U. Siebert, M. Mclachlan, R. Bruhn, K. Thron, K. Failing, G. Muller, and W. Baumgartner. (2005b). Investigations of the potential influence of environmental contaminants on the thymus and spleen of harbor porpoises (*Phocoena phocoena*). *Environ Sci Technol* 39:3933-3938.

Berggrena, P., R. Ishaq, Y. Zebuhr, C. Naf, C. Bandh, and B. D. (1999). Patterns and levels of organochlorines (DDTs, PCBs, non-*ortho* PCBs and PCDD/Fs) in male harbour porpoises (*Phocoena phocoena*) from the Baltic sea, the Kattegat-Skagerrak seas and the west coast of Norway. *Mar Poll Bull* 38:1070-1084.

Bruhn, R., N. Kannan, G. Petrick, D. E. Schulz-Bull, and J. C. Duinker. (1995). CB pattern in the harbour porpoise: bioaccumulation, metabolism and evidence for cytochrome P450 IIB activity. I 31:3721-3732.

Calambokidis, J., K. M. Langelier, P. J. Stacey, and R. Baird. (1990). Environmental contaminants in killer whales from Washington, British Columbia and Alaska. Abstract submitted to the third International Orca Symposium, Victoria B.C.

Clausen, J., L. Braestrup, and O. Berg. (1974). The content of polychlorinated hydrocarbons in Arctic mammals. *Bulletin of Environmental Contamination and Toxicology* 12:529-534.

Elfes, C. T., G. R. VanBlaricom, D. Boyd, J. Calambokidis, P. J. Clapham, R. W. Pearce, J. Robbins, J. C. Salinas, J. M. Straley, P. R. Wade, and M. M. Krahn. (2010).

Geographic Variation of Persistent Organic Pollutant Levels in Humpback Whale (*Megaptera Novaeangliae*) Feeding Areas of the North Pacific and North Atlantic. *Environmental Toxicology and Chemistry* 29:824-834.

Fair, P. A., J. Adams, G. Mitchum, T. C. Hulsey, J. S. Reif, M. Houde, D. Muir, E. Wirth, D. Wetzel, E. Zolman, W. McFee, and G. D. Bossart. (2010). Contaminant blubber burdens in Atlantic bottlenose dolphins (*Tursiops truncatus*) from two southeastern US estuarine areas: concentrations and patterns of PCBs, pesticides, PBDEs, PFCs, and PAHs. *Sci Total Environ* 408:1577-1597.

Gaskin, D. E., R. Frank, and M. Holdrinet. (1983). Polychlorinated biphenyls in harbor porpoises *Phocoena phocoena* (L) from the Bay of Fundy, Canada and adjacent waters with some information on chlordane and hexachlorobenzene levels. *Archives of Environmental Contamination and Toxicology* 12:211-219.

Gauthier, J. M., C. D. Metcalfe, and R. Sears. (1997). Chlorinated organic contaminants in blubber biopsies from northwestern Atlantic balaenopterid whales summering in the Gulf of St Lawrence. *Marine Environmental Research* 44:201-223.

Granby, K., and C. C. Kinze. (1991). Organochlorines in Danish and West Greenland harbour porpoises. *Marine Pollution Bulletin* 22:458-462.

Harms, U., H. E. Drescher, and E. Huschenbeth. (1977). Further data on heavy metals and organochlorines in marine mammals from German coastal waters. *International Council for the Exploitation of the Seas* N:5:1-11.

Holden, A. V., and K. Marsden. (1967). Organochlorine pesticides in seals and porpoises. *Nature* 216:1274-1276.

Jaber, J. R., J. Perez, M. Carballo, M. Arbelo, A. Espinosa de los Monteros, P. Herraez, J. Munoz, M. Andrada, F. Rodriguez, and A. Fernandez. (2005). Hepatosplenic large cell immunoblastic lymphoma in a bottlenose dolphin (*Tursiops truncatus*) with high levels of polychlorinated biphenyl congeners. *J Comp Pathol* 132:242-247.

Jarman, W. M., R. J. Norstrom, D. C. G. Muir, B. Rosenberg, M. Simon, and R. W. Baird. (1996). Levels of organochlorine compounds, including PCDDS and PCDFS, in the blubber of cetaceans from the west coast of North America. *Marine Pollution Bulletin* 32:426-436.

Kannan, K., S. Tanabe, A. Borrell, A. Aguilar, S. Focardi, and R. Tatsukawa. (1993). Isomer-specific analysis and toxic evaluation of polychlorinated biphenyls in striped dolphins affected by an epizootic in the western Mediterranean sea. *Arch Environ Contam Toxicol* 25:227-233.

Kleivane, L., J. U. Skaare, A. Bjorge, E. De Ruiter, and P. J. Reijnders. (1995). Organochlorine pesticide residue and PCBs in harbour porpoise (*Phocoena phocoena*) incidentally caught in Scandinavian waters. *Environ Pollut* 89:137-146.

Kuiken, T., P. M. Bennett, C. R. Allchin, J. K. Kirkwood, J. R. Baker, C. H. Lockyer, M. J. Walton, and M. C. Sheldrick. (1994). PCBs, cause of death and body condition in harbour porpoises *Phocoena phocoena* from British waters. *Aquatic Toxicology* 28:13-28.

Law, R. J., J. Barry, J. L. Barber, P. Bersuder, R. Deaville, R. J. Reid, A. Brownlow, R. Penrose, J. Barnett, J. Loveridge, B. Smith, and P. D. Jepson. (2012). Contaminants in cetaceans from UK waters: Status as assessed within the Cetacean Strandings Investigation Programme from 1990 to 2008. *Marine Pollution Bulletin* 64:1485-1494.

Morris, R. J., R. J. Law, C. R. Allchin, C. A. Kelly, and C. F. Fileman. (1989). Metals and organochlorines in dolphins and porpoises of Cardigan Bay, West Wales. *Marine Pollution Bulletin* 20:512-523.

Strandberg, B., C. Bandh, B. van Bavel, P. A. Bergqvist, D. Broman, C. Naf, H. Pettersen, and C. Rappe. (1998a). Concentrations, biomagnification and spatial variation of organochlorine compounds in a pelagic food web in the northern part of the Baltic Sea. *Sci Total Environ* 217:143-154.

Strandberg, B., L. Strandberg, P. A. Bergqvist, J. Falandysz, and C. Rappe. (1998b) Concentrations and biomagnification of 17 chlordane compounds and other organochlorines in harbour porpoise (*Phocoena phocoena*) and herring from the southern Baltic Sea. *Chemosphere* 37:2513-2523.

Tanabe, S., B. Madhusree, A. A. Ozturk, R. Tatsukawa, N. Miyazaki, E. Ozdamar, O. Aral, O. Samsun, and B. Ozturk. (1997). Isomer-specific analysis of polychlorinated biphenyls in harbour porpoise (*Phocoena phocoena*) from the Black Sea. *Marine Pollution Bulletin* 34:712-720.

Troisi, G. M., and C. F. Mason. (1997). Cytochromes P450, P420 and mixed-function oxidases as biomarkers of polychlorinated biphenyl (PCB) exposure in harbour seals (*Phoca vitulina*). *Chemosphere* 35:1933-1946.

van Scheppingen, W. B., A. Verhoeven, P. Mulder, M. J. Addink, and C. Smeenk. (1996). Polychlorinated Biphenyls, Dibenzo-p-dioxins, and Dibenzofurans in Harbor Porpoises (*Phocoena phocoena*) Stranded on the Dutch Coast Between 1990 and (1993). *Arch Environ Contam Toxicol* 30:492-502.

Vetter, W., B. Luckas, G. Heidemann, and K. Skirnisson. (1996). Organochlorine residues in marine mammals from the Northern hemisphere - A consideration of the composition of organochlorine residues in the blubber of marine mammals. *Science of the Total Environment* 186:29-39.

Weijs, L., R. S. H. Yang, A. Covaci, K. Das, and R. Blust. (2010). Physiologically based pharmacokinetic (PBPK) models for lifetime exposure to PCB 153 in male and female harbor porpoises (*Phocoena phocoena*): model development and evaluation. *Environmental Science & Technology* 44:7023-7030.

Wells, D. E., L. A. Campbell, H. M. Ross, P. M. Thompson, and C. H. Lockyer. (1994). Organochlorine residues in harbour porpoise and bottlenose dolphins stranded on the coast of Scotland, 1988-1991. *Sci Total Environ* 151:77-99.

Appendix 1.2

References for data on mercury

Augier, H., Benkoel, L., Chamlian, A., Park, W.K. & Ronneau, C. (1993). Mercury zinc and selenium bioaccumulation in tissues and organs of Mediterranean striped dolphins (*Stenella coeruleoalba*) toxicological result of their interaction. *Cell. Mol. Biol.*, 39, 621-634.

Baptista, G., Kehrig, H.A., Di Beneditto, A.P.M., Hauser-Davis, R.A., Almeida, M.G., Rezende, C.E. *et al.* (2016). Mercury, selenium and stable isotopes in four small cetaceans from the Southeastern Brazilian coast: Influence of feeding strategy. *Environ. Pollut.*, 218, 1298-1307.

Bustamante, P., Garrigue, C., Breau, L., Caurant, F., Dabin, W., Greaves, J. *et al.* (2003). Trace elements in two odontocete species (*Kogia breviceps* and *Globicephala macrorhynchus*) stranded in New Caledonia (South Pacific). *Environ. Pollut.*, 124, 263-271.

Cardellicchio, N., Giandomenico, S., Ragone, P. & Di Leo, A. (2000). Tissue distribution of metals in striped dolphins (Stenella coeruleoalba) from the Apulian coasts, Southern Italy. *Mar. Environ. Res.*, 49, 55-66.

Cardellicchio, N., Decataldo, A., Di Leo, A. & Giandomenico, S. (2002a). Trace elements in organs and tissues of striped dolphins (*Stenella coeruleoalba*) from the Mediterranean sea (Southern Italy). *Chemosphere*, 49, 85-90.

Cardellicchio, N., Decataldo, A., Di Leo, A. & Misino, A. (2002b). Accumulation and tissue distribution of mercury and selenium in striped dolphins (*Stenella coeruleoalba*) from the Mediterranean Sea (southern Italy). *Environ. Pollut.*, 116, 265-271.

Cecilio, P., Raimundo, J., Canario, J., Vale, C. & Sequeira, M. (2006). Relationships between total and organic mercury concentrations in tissues and length of common dolphins (*Delphinus delphis*) from the Portuguese coast. *Cienc. Mar.*, 32, 379-387.

Chen, M.H., Shih, C.C., Chou, C.L. & Chou, L.S. (2002). Mercury, organic-mercury and selenium in small cetaceans in Taiwanese waters. *Mar. Poll. Bull.,* 45, 237-245.

Chen, M.H., Zhuang, M.F., Chou, L.S., Liu, J.Y., Shih, C.C. & Chen, C.Y. (2017). Tissue concentrations of four Taiwanese toothed cetaceans indicating the silver and cadmium pollution in the western Pacific Ocean. *Mar. Poll. Bull.,*, 124, 993-1000.

De Carvalho, C.E.V., Di Beneditto, A.P.M., Souza, C.M.M., Ramos, R.M.A. & Rezende, C.E. (2008). Heavy metal distribution in two cetacean species from Rio de Janeiro State, south-eastern Brazil. *J. Mar. Biol.l Assoc.U.K.,* 88, 1117-1120.

Damseaux, F., Kiszka, J.J., Heithaus, M.R., Scholl, G., Eppe, G., Thome, J.P. *et al.* (2017). Spatial variation in the accumulation of POPs and mercury in bottlenose dolphins of the Lower Florida Keys and the coastal Everglades (South Florida). *Environ. Pollut.*, 220, 577-587.

de Moura, J.F., Emin-Lima, R., Hacon, S.S., Vega, C.M., de Campos, R.C. & Siciliano, S. (2012a). Mercury Status of the Amazon Continental Shelf: Guiana Dolphins (*Sotalia guianensis*, Van Beneden, 1864) as a Bioindicator. *Bull. Environ. Contam. Toxicol.*, 89, 412-418.

de Moura, J.F., Hacon, S.D., Vega, C.M., Hauser-Davis, R.A., de Campos, R.C. & Siciliano, S. (2012b). Guiana Dolphins (*Sotalia guianensis*, Van Beneden 1864) as Indicators of the Bioaccumulation of Total Mercury along the Coast of Rio de Janeiro State, Southeastern Brazil. *Bull. Environ. Contam. Toxicol.*, 88, 54-59.

Dirtu, A.C., Malarvannan, G., Das, K., Dulau-Drouot, V., Kiszka, J.J., Lepoint, G. *et al.* (2016). Contrasted accumulation patterns of persistent organic pollutants and mercury in sympatric tropical dolphins from the south-western Indian Ocean. *Environ. Res.*, 146, 263-273.

Dong, W.W., Xu, Y., Wang, D. & Hao, Y.J. (2006). Mercury concentrations in Yangtze finless porpoises (*Neophocaena phocaenoides asiaeorientalis*) from Eastern Dongting Lake, China. *Fres. Environ. Bull.*, 15, 441-447.

Durden, W.N., Stolen, M. K., Adams, D.H. & Stolen, E.D. (2007). Mercury and selenium concentrations in stranded bottlenose dolphins from the Indian River Lagoon system, Florida. *Bull. Mar. Sci.,* 81, 37-54.

Endo, T., Haraguchi, K. & Sakata, M. (2002). Mercury and selenium concentrations in the internal organs of toothed whales and dolphins marketed for human consumption in Japan. *Sci. Total Environ.*, 300, 15-22.

Endo, T., Haraguchi, K. & Sakata, M. (2003a). Renal toxicity in rats after oral administration of mercury-contaminated boiled whale livers marketed for human consumption. *Arch. Environ. Contam. Toxicol.*, 44, 412-416.

Endo, T., Hotta, Y., Haraguchi, K. & Sakata, M. (2003b). Mercury contamination in the red meat of whales and dolphins marketed for human consumption in Japan. *Environ. Sci. Technol.*, 37, 2681-2685.

Endo, T., Haraguchi, K., Cipriano, F., Simmonds, M.P., Hotta, Y. & Sakata, M. (2004). Contamination by mercury and cadmium in the cetacean products from Japanese market. *Chemosphere*, 54, 1653-1662.

Endo, T., Haraguchi, K., Hotta, Y., Hisamichi, Y., Lavery, S., Dalebout, M.L. *et al.* (2005a). Total mercury, methyl mercury, and selenium levels in the red meat of small cetaceans sold for human consumption in Japan. *Environ. Sci. Technol.*, 39, 5703-5708.

Endo, T., Hotta, Y., Haraguchi, K. & Sakata, M. (2005b). Distribution and toxicity of mercury in rats after oral administration of mercury-contaminated whale red meat marketed for human consumption. *Chemosphere*, 61, 1069-1073.

Endo, T., Kimura, O., Hisamichi, Y., Minoshima, Y., Haraguchi, K., Kakumoto, C. *et al.* (2006). Distribution of total mercury, methyl mercury and selenium in pod of killer whales (*Orcinus orca*) stranded in the northern area of Japan: Comparison of mature females with calves. *Environ. Pollut.*, 144, 145-150.

Endo, T., Yong-Un, M., Baker, C.S., Funahashi, N., Layery, S., Dalebout, M.L. *et al.* (2007). Contamination level of mercury in red meat products from cetaceans available from South Korea markets. *Marine Pollution Bulletin*, 54, 669-677.

Endo, T., Hisamichi, Y., Kimura, O., Haraguchi, K. & Baker, C.S. (2008). Contamination levels of mercury and cadmium in melon-headed whales (*Peponocephala electra*) from a mass stranding on the Japanese coast. *Sci. Total Environ.*, 401, 73-80.

Endo, T. & Haraguchi, K. (2010a). High mercury levels in hair samples from residents of Taiji, a Japanese whaling town. *Mar.Poll. Bull.*, 60, 743-747.

Endo, T., Hisamichi, Y., Kimura, O., Haraguchi, K., Lavery, S., Dalebout, M.L. *et al.* (2010b). Stable Isotope Ratios of Carbon and Nitrogen and Mercury Concentrations in 13 Toothed Whale Species Taken from the Western Pacific Ocean off Japan. *Environ. Sci. Technol.*, 44, 2675-2681.

Ferreira, M., Monteiro, S.S., Torres, J., Oliveira, I., Sequeira, M., Lopez, A. *et al.* (2016). Biological variables and health status affecting inorganic element concentrations in harbour porpoises (*Phocoena phocoena*) from Portugal (western Iberian Peninsula). *Environ. Pollut.*, 210, 293-302.

Fielding, R. & Evans, D.W. (2014). Mercury in Caribbean dolphins (*Stenella longirostris and Stenella frontalis*) caught for human consumption off St. Vincent, West Indies. *Mar. Poll. Bull.*, 89, 30-34.

Fontaine, M., Carravieri, A., Simon-Bouhet, B., Bustamante, P., Gasco, N., Bailleul, F. *et al.* (2015). Ecological tracers and at-sea observations document the foraging ecology of southern long-finned pilot whales (*Globicephala melas edwardii*) in Kerguelen waters. *Mar. Biol.*, 162, 207-219.

Frodello, J.P., Romeo, M. & Viale, D. (2000). Distribution of mercury in the organs and tissues of five toothed-whale species of the Mediterranean. *Environ. Pollut.*, 108, 447-452.

Haraguchi, K., Endo, T., Sakata, M., Masuda, Y. & Simmonds, M. (2000). Contamination survey of heavy metals and organochlorine compounds in cetacean products purchased in Japan. *J. Food Hyg. Soc. Japan*, 41, 287-296.

Hung, C.L.H., Lau, R.K.F., Lam, J.C.W., Jefferson, T.A., Hung, S.K., Lam, M.H.W. *et al.* (2007). Risk assessment of trace elements in the stomach contents of Indo-Pacific Humpback Dolphins and Finless Porpoises in Hong Kong waters. *Chemosphere*, 66, 1175-1182.

Hung, C.L.H., So, M.K., Connell, D.W., Fung, C.N., Lam, M.H.W., Nicholson, S. *et al.* (2004). A preliminary risk assessment of trace elements accumulated in fish to the

Indo-Pacific Humpback dolphin (*Sousa chinensis*) in the Northwestern waters of Hong Kong. *Chemosphere*, 56, 643-651.
Joiris, C.R., Holsbeek, L., Bolba, D., Gascard, C., Stanev, T., Komakhidze, A. *et al.* (2001). Total and organic mercury in the Black Sea harbour porpoise *Phocoena phocoena relicta*. *Mar. Poll. Bull*, 42, 905-911.
Kunito, T., Watanabe, I., Yasunaga, G., Fujise, Y. & Tanabe, S. (2002). Using trace elements in skin to discriminate the populations of minke whales in southern hemisphere. *Mar.Environ. Res.*, 53, 175-197.
Law, R.J., Allchin, C.R., Jones, B.R., Jepson, P.D., Baker, J.R. & Spurrier, C.J.H. (1997). Metals and organochlorines in tissues of a Blainville's beaked whale (*Mesoplodon densirostris*) and a killer whale (*Orcinus orca*) stranded in the United Kingdom. *Mar. Poll. Bull.*, 34, 208-212.
Lemos, L.S., de Moura, J.F., Hauser-Davis, R.A., de Campos, R.C. & Siciliano, S. (2013). Small cetaceans found stranded or accidentally captured in southeastern Brazil: Bioindicators of essential and non-essential trace elements in the environment. *Ecotox. Environ. Safe.*, 97, 166-175.
Mackey, E.A., Oflaz, R.D., Epstein, M.S., Buehler, B., Porter, B.J., Rowles, T. *et al.* (2003). Elemental composition of liver and kidney tissues of rough-toothed dolphins (*Steno bredanensis*). *Arch. Environ. Contam. Toxicol.*, 44, 523-532.
Monteiro-Neto, C., Itavo, R.V. & Moraes, L.E.D. (2003). Concentrations of heavy metals in Sotalia fluviatilis (Cetacea : Delphinidae) off the coast of Ceara, northeast Brazil. *Environ. Pollut.*, 123, 319-324.
Parsons, E.C.M. (1999). Trace element concentrations in the tissues of cetaceans from Hong Kong's territorial waters. *Environ. Cons.*, 26, 30-40.
Reed, L.A., McFee, W.E., Pennington, P.L., Wirth, E.F. & Fulton, M.H. (2015). A survey of trace element distribution in tissues of the dwarf sperm whale (*Kogia sima*) stranded along the South Carolina coast from 1990-2011. *Mar. Poll. Bull*, 100, 501-506.
Roditi-Elasar, M., Kerem, D., Hornung, H., Kress, N., Shoham-Frider, E., Goffman, O. *et al.* (2003). Heavy metal levels in bottlenose and striped dolphins off the Mediterranean coast of Israel. *Mar. Poll. Bull*, 46, 503-512.
Seixas, T.G., Kehrig, H.D.A., Fillmann, G., Di Beneditto, A.P.M., Souza, C.M.M., Seechi, E.R. *et al.* (2007). Ecological and biological determinants of trace elements accumulation in liver and kidney of Pontoporia blainvillei. *Sci. Total Environ.*, 385, 208-220.
Seixas, T.G., Kehrig, H.A., Di Beneditto, A.P.M., Souza, C.M.M., Malm, O. & Moreira, I. (2009). Trace Elements in Different Species of Cetacean from Rio de Janeiro Coast. *J Brazil Chem Soc*, 20, 243-251.
Shoham-Frider, E., Amiel, S., Roditi-Elasar, M. & Kress, N. (2002). Risso's dolphin (*Grampus griseus*) stranding on the coast of Israel (eastern Mediterranean). Autopsy results and trace metal concentrations. *Sci. Total Environ.*, 295, 157-166.
Shoham-Frider, E., Kress, N., Wynne, D., Scheinin, A., Roditi-Elsar, M. & Kerem, D. (2009). Persistent organochlorine pollutants and heavy metals in tissues of common bottlenose dolphin (*Tursiops truncatus*) from the Levantine Basin of the Eastern Mediterranean. *Chemosphere*, 77, 621-627.
Shoham-Frider, E., Kerem, D., Roditi-Elasar, M., Goffman, O., Morick, D., Yoffe, O. *et al.* (2014). Trace elements in tissues of cetacean species rarely stranded along the Israeli Mediterranean coast. *Mar. Poll. Bull*, 83, 376-382.
Simmonds, M.P., Haraguchi, K., Endo, T., Cipriano, F., Palumbi, S.R. & Troisi, G.M. (2002). Human health significance of organochlorine and mercury contaminants in Japanese whale meat. *J. Toxicol. Env. Health Pt a*, 65, 1211-1235.

Squadrone, S., Brizio, P., Chiaravalle, E. & Abete, M.C. (2015). Sperm whales (*Physeter macrocephalus*), found stranded along the Adriatic coast (Southern Italy, Mediterranean Sea), as bioindicators of essential and non-essential trace elements in the environment. *Ecol Indic*, 58, 418-425.

Stavros, H.C.W., Bossart, G.D., Hulsey, T.C. & Fair, P.A. (2007). Trace element concentrations in skin of free-ranging bottlenose dolphins (*Tursiops truncatus*) from the southeast Atlantic coast. *Sci. Total Environ.*, 388, 300-315.

Stavros, H.C.W., Bossart, G.D., Hulsey, T.C. & Fair, P.A. (2008) Trace element concentrations in blood of free-ranging bottlenose dolphins (Tursiops truncatus): Influence of age, sex and location. *Marine Pollution Bulletin*, 56, 371-379.

Stockin, K.A., Law, R.J., Duignan, P.J., Jones, G.W., Porter, L., Mirimin, L. *et al.* (2007). Trace elements, PCBs and organochlorine pesticides in New Zealand common dolphins (Delphinus sp.). *Sci. Total Environ.*, 387, 333-345.

Tilbury, K.L., Stein, J.E., Meador, J.P., Krone, C.A. & Chan, S.L. (1997). Chemical contaminants in harbor porpoise (Phocoena phocoena) from the north Atlantic coast: Tissue concentrations and intra- and inter-organ distribution. *Chemosphere*, 34, 2159-2181.

Titcomb, E.M., Reif, J.S., Fair, P.A., Stavros, H.C.W., Mazzoil, M., Bossart, G.D. *et al.* (2017). Blood mercury concentrations in common bottlenose dolphins from the Indian River Lagoon, Florida: Patterns of social distribution. *Mar. Mam. Sci.*, 33, 771-784.

Woshner, V.M., O'Hara, T.M., Bratton, G.R., Suydam, R.S. & Beasley, V.R. (2001). Concentrations and interactions of selected essential and non-essential elements in bowhead and beluga whales of arctic Alaska. *J. Wildl. Dis.*, 37, 693-710.