Choi, M., Lee, S.J., Koo, J.H., Moon, H.B., Kim, G.Y., 2005. Occurrence and concentrations of estrogenic phenolic compounds in surface waters of rivers flowing into Masan Bay, Korea. Journal of Fisheries Science and Technology 8, 220–227.
Choi, M., Choi, H.G., Moon, H.B., Kim, G.Y., 2009. Spatial and temporal distribution of tributyltin (TBT) in seawater, sediments and bivalves from coastal areas of Korea during 2001–2005. Environmental Monitoring and Assessment 151, 301–310.
Diez, S., Jover, E., Albaiges, J., Bayona, J.M., 2006. Occurrence and degradation of butyltins and wastewater marker compounds in sediments from Barcelona harbor, Spain. Environment International 32, 858–865.
Eganhouse, R.P., Sherblom, P.M., 2001. Anthropogenic organic contaminants in the effluent of a combined sewer overflows: impact on Boston Harbor. Marine Environmental Research 51, 51–74.
Environment Canada, 2002. Canadian environmental quality guidelines for the protection of aquatic life: nonylphenol and its ethoxylates. National guidelines and standards office, Environmental quality branch, Environment Canada, Report 1-3, Ottawa, Canada.
Ferguson, P.L., Iden, C.R., Brownawell, B.J., 2001. Distribution and fate of neutral alkylphenol ethoxylate metabolites in a sewage-impacted urban estuary. Environmental Science and Technology 35, 2428–2435.
Fu, M., Li, Z., Gao, H., 2007. Distribution characteristics of nonylphenol in Jiaozhou Bay of Qingdao and its adjacent rivers. Chemosphere 69, 1009–1016.
Gonzalez-Orefa, J.A., Saiz-Salinas, J.I., 1998. Short-term spatio-temporal changes in urban pollution by means of faecal sterols analysis. Marine Pollution Bulletin 36, 868–875.
Hong, S.H., Yim, U.H., Shim, W.J., Li, D.H., Oh, J.R., 2005. Nationwide monitoring of polychlorinated biphenyls and organochlorine pesticides in sediments from coastal environment of Korea. Chemosphere 64, 1479–1488.
Isobe, K.O., Tarao, M., Zakaria, M.P., Chiem, N.H., Minh, L.Y., Takada, H., 2002. Quantitative application of fecal sterols using gas chromatography–mass spectrometry to investigate fecal pollution in tropical waters: Western Malaysia and Mekong Delta, Vietnam. Environmental Science and Technology 36, 4497–4507.
Isobe, T., Nishiyama, H., Nakashima, A., Takada, H., 2001. Distribution and behavior of nonylphenol, octylphenol and nonylphenol monoethoxylate in Tokyo metropolitan area: their association with aquatic particles and sedimentary distributions. Environmental Science and Technology 35, 1041–1049.
Jonkers, N., Laane, R.W.P.M., De Graaf, C., De Voogt, P., 2005. Fate modeling of nonylphenol ethoxylates and their metabolites in the Dutch Scheldt and Rhine estuaries: validation with new field data. Estuarine, Coastal and Shelf Science 62, 141–160.
Koh, C.H., Khim, J.S., Villeneuve, D.L., Kannan, K., Johnson, B.G., Giesy, J.P., 2005. Instrumental and bioanalytical measures of dioxin-like and estrogenic compounds and activities associated with sediment from the Korean coast. Ecotoxicology and Environmental Safety 61, 366–379.
Koh, C.H., Khim, J.S., Villeneuve, D.L., Kannan, K., Giesy, J.P., 2006. Characterization of trace organic contaminants in marine sediment from Yeongil Bay, Korea: 1. Instrumental analysis. Environmental Pollution 142, 39–47.
Lara-Martin, P.A., Gomez-Parra, A., Gonzalez-Mazo, E., 2008. Sources, transport and reactivity of anionic and non-ionic surfactants in several aquatic ecosystems in SW Spain: a comparative study. Environmental Pollution 156, 36–45.
Lee, H.J., Chattopadhyay, S., Gong, E.Y., Ahn, R.S., Lee, K., 2003. Antiandrogenic effects of bisphenol A and nonylphenol on the function of androgen receptor. Toxicological Sciences 75, 40–46.
Leeming, R., Nichols, P.D., 1996. Concentrations of coprostanol that correspond to existing bacterial indicator guideline limits. Water Research 30, 2997–3006.
Li, D., Dong, M., Shim, W.J., Yim, U.H., Hong, S.H., Kannan, N., 2008. Distribution characteristics of nonylphenolic chemicals in Masan Bay environments, Korea. Chemosphere 71, 1162–1172.
Li, D., Kim, M., Oh, J.R., Park, J., 2004. Distribution characteristics of nonylphenols in the artificial Lake Shihwa, and surrounding creeks in Korea. Chemosphere 56, 783–790.
Li, D., Shim, W.J., Dong, M., Hong, S.H., 2007. Application of nonylphenol and coprostanol to identification of industrial and fecal pollution in Korea. Marine Pollution Bulletin 54, 97–116.
Maldonado, C., Indira Venkatesan, M., Philips, C.R., Bayona, J.M., 2000. Distribution of trialkylamines and coprostanol in San Pedro Sediments adjacent to a sewage outfall. Marine Pollution Bulletin 40, 680–687.
Mayer, T., Bennie, D., Rosa, F., Rekas, G., Palabrica, V., Schachtschneider, J., 2007. Occurrence of alkylphenolic substances in a Great Lakes coastal marsh, Cootes Paradise, ON, Canada. Environmental Pollution 147, 683–690.
MOE (Ministry of Environment), 2006. A designation of nonylphenolic compounds as the restricted chemical in Korea. Seoul, Environmental Policy Office, Department of Hazardous Chemical Management, <http://me.korea.kr/me/jsp/me1_branch.jsp?_action=news_view&_property=p_sec_1&_id=155140348&>.
MOE, 2007. Statistics of industrial wastewaters. Seoul, Water Environment Management Bureau, Industrial Wastewater Control Division. p. 271 (in Korean).
Moon, H.B., Kannan, K., Lee, S.J., Choi, M., 2007. Polybrominated diphenyl ethers (PBDEs) in sediment and bivalves from Korean coastal waters. Chemosphere 66, 243–251.
Moon, H.B., Choi, H.G., Lee, P.Y., Ok, G., 2008a. Congener-specific characterization and sources of polychlorinated dibenzo-p-dioxins, dibenzofurans and dioxin-like polychlorinated biphenyls in marine sediments from industrialized bays of Korea. Environmental Toxicology and Chemistry 27, 323–333.
Moon, H.B., Yoon, S.P., Jung, R.H., Choi, M., 2008b. Wastewater treatment plants (WWTPs) as a source of sediment contamination by toxic organic pollutants and fecal sterols in a semi-enclosed bay in Korea. Chemosphere 73, 880–889.
Mudge, S.M., Lintern, D.G., 1999. Comparison of sterol biomarkers for sewage with other measures in Victoria Harbour, BC, Canada. Estuarine, Coastal and Shelf Science 48, 27–38.
O'Connor, T.P., 2002. National distribution of chemical concentrations in mussels and oysters in the USA. Marine Environmental Research 53, 117–143.
Peng, X., Zhang, G., Mai, B., Min, Y., Wang, Z., 2002. Spatial and temporal trend of sewage pollution indicated by coprostanol in Macao Estuary, Southern China. Marine Pollution Bulletin 45, 295–299.
Rule, K.L., Comber, S.D.W., Ross, D., Thornton, D.R., Makropoulos, C.K., Rautiu, R., 2006. Sources of priority substances entering an urban wastewater catchment – trace organic chemicals. Chemosphere 63, 581–591.
Soares, A., Guieysse, B., Jefferson, B., Cartmell, E., Lester, J.N., 2008. Nonylphenol in the environment: a critical review on occurrence, fate, toxicity and treatment in wastewaters. Environment International 34, 1033–1049.
Thiele, B., Gunther, K., Schwuger, M.J., 1997. Alkylphenol ethoxylates: trace analysis and environmental behavior. Chemical Review 97, 3247–3272.
Yim, U.H., Hong, S.H., Shim, W.J., 2007. Distribution and characteristics of PAHs in sediments from the marine environment of Korea. Chemosphere 68, 85–92.

0025-326X/$ - see front matter
doi:10.1016/j.marpolbul.2009.04.010

Evidence for increased ingestion of plastics by northern fulmars (*Fulmarus glacialis*) in the Canadian Arctic

Jennifer F. Provencher [a,*], Anthony J. Gaston [b], Mark L. Mallory [c]

[a] *University of Victoria, Department of Biology, P.O. Box 3020, Station CSC, Victoria, BC, Canada V8W 3N5*
[b] *Science and Technology Branch, National Wildlife Research Centre, Raven Road, Carleton University, Ottawa, ON, Canada K1A 0H3*
[c] *Canadian Wildlife Service, P.O. Box 1714, Iqaluit, NU, Canada X0A 0H0*

Marine plastic debris floating in the oceans is a worldwide problem. When ingested by seabirds it may cause starvation and reduced growth, as well as more subtle effects that can be difficult to detect, including reduced dietary efficiency and increased levels of PCBs and other organochlorine assimilation (van Franeker, 1985; Dickerman and Goelet, 1987; Ryan, 1988; Ryan et al., 1988). Globally, the incidence of plastics in seabirds has increased since it was first reported in 1960 (Harper and Fowler, 1987; Moser and Lee, 1992; Petry et al., 2007). By 2008, ingested plastic debris has been reported in more than 200 seabird species (Moore, 2008), and is a problem even in isolated and remote colonies (Van Franeker and Bell, 1988).

The northern fulmar, *Fulmarus glacialis*, a medium-sized petrel with a circumpolar distribution, is particularly vulnerable to

* Corresponding author. Tel.: +1 2504725098; fax: +1 2507217120.
E-mail address: jennipro@uvic.ca (J.F. Provencher).

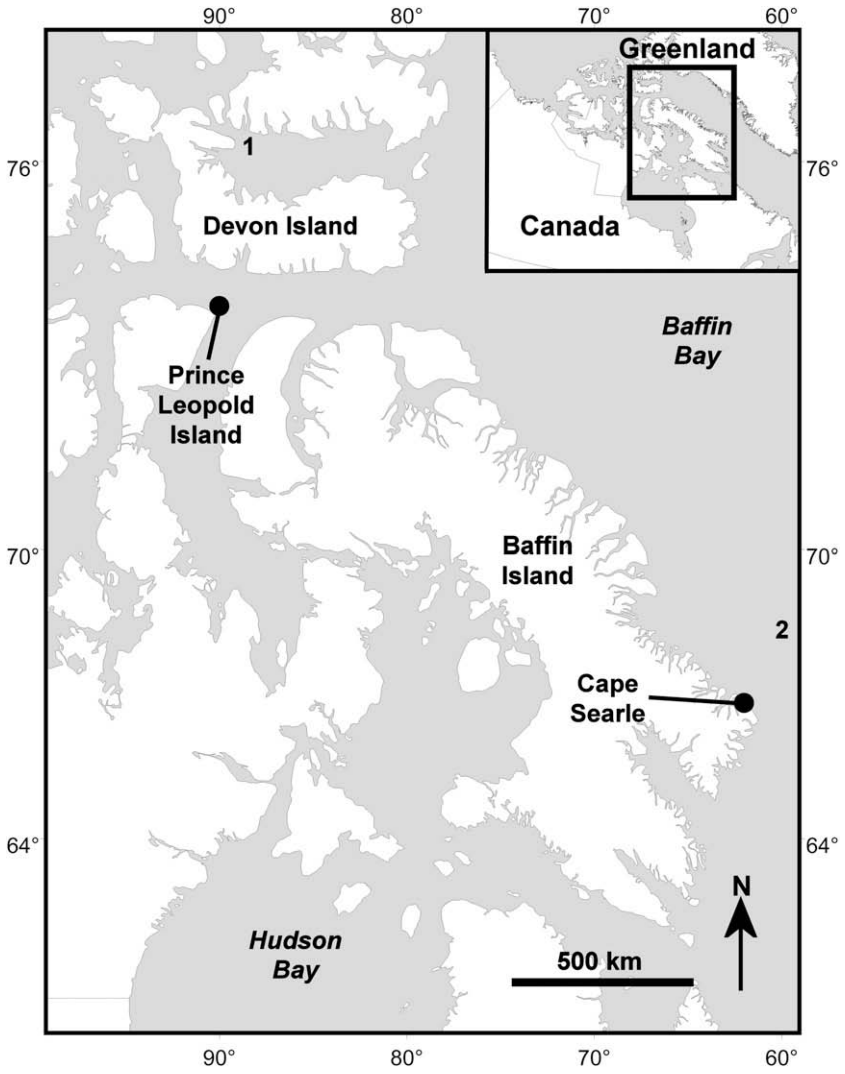

Fig. 1. Northern fulmars were collected at two colonies in the Canadian Arctic: Prince Leopold Island, and Cape Searle. Sites where previous studies have documented plastic ingestion by fulmars are noted as "1" (Cape Vera; Mallory, 2008) and "2" (Davis Strait; Mallory et al., 2006).

ingesting marine plastic debris and was one of the first species in which a high incidence of plastic ingestion was reported among North Atlantic seabirds (Baltz and Morejohn, 1976; Bourne, 1976; Furness, 1985). Because they ingest and retain a wide variety of plastic debris (van Franeker and Meijboom, 2006), fulmars are useful indicators of trends in marine debris in offshore areas. The incidence of plastics in their stomachs has been used as an indicator of marine debris in the North Sea since the 1980s (van Franeker et al., 2005). Unlike Europe's North Sea, the Canadian Arctic is remote from industrial centres and major shipping lanes. In the 1970s, Bradstreet (1976) collected Arctic fulmars for dietary analysis and reported no ingested plastic, despite the contemporary occurrence of debris in seabirds elsewhere (Baltz and Morejohn, 1976; Harper and Fowler, 1987; Moser and Lee, 1992). The first evidence of ingested plastic in breeding fulmars in the Canadian Arctic was recorded in 2003 by Mallory (2008) who sampled northern fulmars from Cape Vera, a breeding colony in the High Arctic.

In this study, we collected fulmars for dietary analysis and contaminant studies at two different colonies in the Canadian Arctic (Fig. 1). Our collections were made at colonies >250 km south of Cape Vera, where Mallory (2008) first reported ingested plastics in breeding fulmars, and thus our collections were closer to shipping traffic and with a longer open water season. Previous studies have shown that incidence of plastic pieces in fulmars is lower at higher latitudes (van Franeker, 1985; Mallory, 2008), however, the sites we sampled were still in Arctic environments constrained by sea ice, and thereby with limited sea traffic and with no industrial activity nearby.

In August 2008, 15 fulmars were shot at sea with a shotgun within 5 km of the fulmar colony at Cape Searle, Nunavut (67°15′N, 62°35′W). Farther north, 10 breeding adults with eggs or chicks were captured on their nest sites with a noose pole on the cliffs at Prince Leopold Island, Nunavut (PLI) (74°N, 90°W), and were immediately euthanized. Each carcass was kept cool until it could be placed in a freezer (within 24 h) and shipped to the laboratory. In November 2008, the carcasses were thawed, measured (standard metrics including body mass), and dissected. The gastrointestinal tracts were removed intact, refrozen, and sent to the University of Victoria for processing and sorting, while the remains of the birds were processed and entered into the National Tissue Bank at the National Wildlife Research Centre in Ottawa for other analyses. Each gastrointestinal tract was later thawed, slit along their entire length, flushed with ethanol to remove all items present,