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Marine Science Review – 393

Contaminants and pollution

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In this review:

O / A **denotes an open access article or journal**

A. Recent articles – no abstract

Jernelöv, A. How to defend against future oil spills. *Nature* 466(7303): 182-183, 2010.

B. Recent articles with abstracts

Blackburn, J.K., Mitchell, M.A., Blackburn, M.C.H., Curtis, A., and Thompson, B.A. Evidence of antibiotic resistance in free-swimming, top-level marine predatory fishes. *Journal of Zoo and Wildlife Medicine* 41(1): 7-16, 2010.

Notes: Antibiotic resistance in bacteria is a growing problem in both human and veterinary medicine. Several studies documented the presence of resistant bacteria in humans, livestock, and domestic animals; however, limited research is available on the presence of antibiotic drug resistance in wildlife species. A cross-sectional study was conducted to estimate the prevalence of resistant bacteria collected from wild-caught, marine predatory fishes. Seven species of sharks and a single teleost species were opportunistically sampled from six different study sites in coastal Belize, coastal and nearshore waters of Louisiana, the Florida Keys, and Martha's Vineyard, Massachusetts. A total of 134 viable bacteria samples were isolated from the cloacal swabs of predatory fishes. Isolates were characterized by Gram-stain morphology and tested for resistance by using the Kirby-Bauer disc diffusion method. Thirteen drugs (penicillin G, piperacillin, ticarcillin, cefotaxime, ceftazidime, ceftiofur, amikacin, gentamicin, ciprofloxacin, enrofloxacin, doxycycline, chloramphenicol, and sulfamethoxazole) were selected for this study. Prevalence was calculated as the total number of isolates resistant to one or more drugs against the total number of samples in that study area or fish population. Sharks sampled in the Florida Keys exhibited the greatest resistance to a wide selection of drugs. Resistance to at least one drug was found in each of the six study sites and in all of the fish species sampled. Multidrug resistance was also documented in most of the study sites. Interspecific comparisons between redfish, *Sciaenops ocellaia*, and sharks from Louisiana offshore waters (which represent species of the *Carcharhinus* genus) demonstrated a significantly higher prevalence in redfish, which may be because of the older age of the population. The findings of this study confirmed the presence of antibiotic-resistant bacteria in marine predatory fishes from multiple taxa and multiple geographic locations.

Tiedeken, J.A. and Ramsdell, J.S. Zebrafish seizure model identifies *p,p'*-DDE as the dominant contaminant of fetal California sea lions that accounts for synergistic activity with domoic acid. *Environmental Health Perspectives* 118(4): 545-551, 2010. O / A

Notes: BACKGROUND: Fetal poisoning of California sea lions (CSLs; *Zalophus californianus*) has been associated with exposure to the algal toxin domoic acid. These same sea lions accumulate a mixture of persistent environmental contaminants including pesticides and industrial products such as polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers

(PBDEs). Developmental exposure to the pesticide dichlorodiphenyltrichloroethane (DDT) and its stable metabolite 1,1-bis-(4-chlorophenyl)-2,2-dichloroethene (*p,p'*-DDE) has been shown to enhance domoic acid induced seizures in zebrafish; however, the contribution of other co-occurring contaminants is unknown. OBJECTIVE: We formulated a mixture of contaminants to include PCBs, PBDEs, hexachlorocyclohexane (HCH), and chlordane at levels matching those reported for fetal CSL blubber to determine the impact of co-occurring persistent contaminants with *p,p'*-DDE on chemically induced seizures in zebrafish as a model for the CSLs. METHODS: Embryos were exposed (6-30 hr postfertilization) to *p,p'*-DDE in the presence or absence of a defined contaminant mixture prior to neurodevelopment via either bath exposure or embryo yolk sac microinjection. After brain maturation (7 days postfertilization), fish were exposed to a chemical convulsant, either pentylenetetrazole or domoic acid; resulting seizure behavior was then monitored and analyzed for changes, using cameras and behavioral tracking software. RESULTS: Induced seizure behavior did not differ significantly between subjects with embryonic exposure to a contaminant mixture and those exposed to *p,p'*-DDE only. CONCLUSION: These studies demonstrate that *p,p'*-DDE in the absence of PCBs, HCH, chlordane, and PBDEs that co-occur in fetal sea lions accounts for the synergistic activity that leads to greater sensitivity to domoic acid seizures.

Storelli, M.M. and Perrone, V.G. Detection and quantitative analysis of organochlorine compounds (PCBs and DDTs) in deep sea fish liver from Mediterranean Sea. *Environmental Science and Pollution Research* 17(4): 968-976, 2010.

Notes: Polychlorinated biphenyls (PCB) and dichlorodiphenyltrichloroethane (DDT) concentrations were determined in the liver of two deep sea fish species, Mediterranean slimehead and blackfin sorcerer, from the Adriatic Sea (southeastern Mediterranean Sea). The examination of congener profiles showed that hexachlorinated molecules were dominant (hexa-CBs, 55.3-56.2%), followed by penta-CBs (21.5-21.8%) and hepta-PCB 180 (14.9-16.0%). PCB 138, 153 and 180 were the prominent congeners accounting for 69.3% of the total PCBs. Among the compounds of DDT, *p,p'*-DDE was the most dominant molecule (Mediterranean slimehead, 86.6%; blackfin sorcerer, 92.8%), demonstrating the old age of these compounds in the environment. In both species, PCB contents were higher than those of DDTs. Contaminant load was higher in Mediterranean slimehead (PCBs, 1,086 ng g^{-1} lipid weight; DDTs, 799 ng g^{-1} lipid weight) than in blackfin sorcerer (PCBs, 561 ng g^{-1} lipid weight; DDTs, 224 ng g^{-1} lipid weight). The high ratios ΣPCBs/ΣDDTs indicated predominantly industrial versus agrarian activities in the area. Dioxins toxic equivalent (TEQ) concentrations (8.1-18.7 pg TEQ per gram wet weight) reached those encountered in marine organisms at higher levels in the trophic chain, revealing the onerous status of contamination by PCBs in Mediterranean deep sea biota.

Rodrigues, R.V., Miranda-Filho, K.C., Gusmao, E.P., Moreira, C.B., Romano, L.A., and Sampaio, L.A. Deleterious effects of water-soluble fraction of petroleum, diesel and gasoline on marine pejerrey *Odontesthes argentinensis* larvae. *The Science of the Total Environment* 408(9): 2054-2059, 2010.

Notes: Accidental discharges and oil spills are frequent around the world. Petroleum-derived hydrocarbons are considered one of the main pollutants of aquatic ecosystem. The importance of petroleum and refined fuels is notorious because today's society depends on them. Researches related to the toxic water-soluble fraction (WSF) of petroleum and derivatives to aquatic biota are scarce. For this reason, deleterious effects of WSF of Brazilian petroleum, automotive diesel and unleaded gasoline to marine pejerrey *Odontesthes argentinensis* larvae were studied employing toxicity tests and histopathological examination. Each WSF was generated in a laboratory by mixing four parts of seawater with one part of pollutant by approximately 22 h. Larvae were exposed during 96 h to different concentrations of WSF of petroleum, diesel, and gasoline, plus a control. After 96 h of exposure to the different WSFs, three larvae were sampled for histo-pathological studies. The median lethal concentration after 96 h (LC_{50}) of exposure for WSF of petroleum was equal to 70.68%, it was significantly higher ($P < 0.05$) than the values for WSF of diesel and gasoline, which were 13.46% and 5.48%, respectively. The histological examination of pejerrey larvae exposed to WSF of petroleum, diesel and gasoline after 96 h revealed a variety of lesions in the larvae. The gills, pseudobranchs and esophagus presented epithelial hyperplasia, and the liver presented dilatation of hepatic sinusoids, hepatocitomegaly, bi-nucleated and nuclear degeneration of hepatocytes, such as pyknotic nuclei. The acute toxicity of diesel and gasoline is at least fivefold higher than Brazilian petroleum. However, all toxicants induced histopathological abnormalities in pejerrey larvae. The results are of importance since much attention has been paid to large visible surfaces of petroleum spills instead of potential toxic effects of dissolved aromatic hydrocarbons, which are more available to marine biota.

Vila, J., Nieto, J.M., Mertens, J., Springael, D., and Grifoll, M. Microbial community structure of a heavy fuel oil-degrading marine consortium: linking microbial dynamics with polycyclic aromatic hydrocarbon utilization. *FEMS Microbiology Ecology* 73(2): 349-362, 2010.

Notes: A marine microbial consortium obtained from a beach contaminated by the *Prestige* oil spill proved highly efficient in removing the different hydrocarbon families present in this heavy fuel oil. Seawater cultures showed a complete removal of all the linear and branched alkanes, an extensive attack on three to five-ring polycyclic aromatic hydrocarbons [PAHs; including anthracene, fluoranthene, pyrene, benzo(*a*)anthracene, chrysene, and benzo(*a*)pyrene] (30-100%), and a considerable depletion of their alkyl derivatives. Community dynamics analysis revealed that *Alcanivorax* species, known alkane degraders, predominated in the initial stages. This was followed by an increase in *Alphaproteobacteria* (i.e. *Maricaulis*, *Roseovarius*), which coincided with the depletion of low molecular PAHs. Finally, these were succeeded by *Gammaproteobacteria* (mainly *Marinobacter* and *Methylophaga*), which were involved in the degradation of the high molecular-weight PAHs. The role of these populations in the removal of the specific components was confirmed by the analysis of subcultures established using the aliphatic or the aromatic fraction of the fuel oil, or single PAHs, as carbon sources. The genus *Marinobacter* seemed to play a major role in the degradation of a variety of hydrocarbons, as several members of this group were isolated from the different enrichment cultures and grew on plates with hexadecane or single PAHs as sole carbon sources.

Scown, T.M., van Aerle, R., and Tyler, C.R. Do engineered nanoparticles pose a significant threat to the aquatic environment? *Critical Reviews in Toxicology* 40(7): 653-670, 2010.

Notes: Nanotechnology is a rapidly growing industry of global economic importance, exploiting the novel characteristics of materials manufactured at the nanoscale. The properties of engineered nanoparticles (ENPs) that make them useful in a wide range of industrial applications, however, have led to concerns regarding their potential impact on human and environmental health. The aquatic environment is particularly at risk of exposure to ENPs, as it acts as a sink for most environmental contaminants. This paper critically evaluates what is currently known about sources and discharge of ENPs to the aquatic environment and how the physicochemical characteristics of ENPs affect their fate and behaviour and thus availability for uptake into aquatic organisms, and assesses reported toxicological effects. Having reviewed the ecotoxicological information, the conclusion is that whilst there are data indicating some nanoparticles have the potential to induce harm in exposed aquatic organisms, there is insufficient evidence for harm, for known/modelled environmental concentrations for almost all ENPs considered. This conclusion, however, must be balanced by the fact that there are significant gaps in our understanding on the fate and behaviour of ENPs in the aquatic environment. Greater confidence in the assessments on ENP impacts in aquatic systems to enable effective comparisons across studies urgently requires more standardised approaches for ENP hazard identification, and critically, more thorough characterisations on the exposed particles. There is also an urgent need for the advancement of tools and techniques that can accurately quantify and visualise uptake of nanoparticles into biological tissues.

Galloway, T., Lewis, C., Dolciotti, I., Johnston, B.D., Moger, J., and Regoli, F. Sublethal toxicity of nano-titanium dioxide and carbon nanotubes in a sediment dwelling marine polychaete. *Environmental Pollution* 158(5): 1748-1755, 2010.

Notes: The ecotoxicology of manufactured nanoparticles (MNPs) in estuarine environments is not well understood. Here we explore the hypothesis that nanoTiO_2 and single walled nanotubes (SWNT) cause sublethal impacts to the infaunal species *Arenicola marina* (lugworm) exposed through natural sediments. Using a 10 day OECD/ASTM 1990 acute toxicity test, no significant effects were seen for SWNT up to 0.03 g/kg and no uptake of SWNTs into tissues was observed. A significant decrease in casting rate ($P = 0.018$), increase in cellular damage ($P = 0.04$) and DNA damage in coelomocytes ($P = 0.008$) was measured for nanoTiO_2, with a preliminary LOEC of 1 g/kg. Coherent anti-stokes Raman scattering microscopy (CARS) located aggregates of TiO_2 of >200 nm within the lumen of the gut and adhered to the outer epithelium of the worms, although no visible uptake of particles into tissues was detected.

Kroeze, C., Dumont, E., and Seitzinger, S. Future trends in emissions of N_2O from rivers and estuaries. *Journal of Integrative Environmental Sciences* 7(S1): 71-78, 2010.

Notes: Emissions of nitrous oxide (N_2O) from aquatic systems such as rivers and estuaries are enhanced as a result of human activities on land resulting in enhanced nitrogen availability in aquatic systems. These human activities include agricultural activities such as fertilizer use, as well as industrial activities resulting in nitrogen (N) losses to the environment. In this article, we analyze past and future trends in global emissions of N_2O from rivers and estuaries. We calculate aquatic N_2O emissions from trends in the export of nitrogen to coastal waters by world-wide rivers. These trends in riverine N exports are from the Global NEWS models, which are global, regionally explicit models developed in the NEWS (Nutrient Export from WaterShed) framework. The NEWS models calculate nutrient exports from land to coastal waters, taking into account different human activities on the land, as well as biological N_2 fixation and different ways in which nitrogen is retained in watersheds, including the effect of dams. We present global total emissions of N_2O for the years 1970, 2000, and for four scenarios for 2050, as well as regional patterns.

Tsapakis, M., Dakanali, E., Stephanou, E.G., and Karakassis, I. PAHs and n-alkanes in Mediterranean coastal marine sediments: aquaculture as a significant point source. *Journal of Environmental Monitoring* 12(4): 958-963, 2010.

Notes: The occurrence of polycyclic aromatic and aliphatic hydrocarbons in fish feed, sediment trap material and marine sediments was examined at two fish farms in the eastern Mediterranean. The average (min-max) concentrations of polycyclic aromatic hydrocarbons (PAHs) in fish feed and particulate effluents were 316 (287-351) ng g^{-1} DW and 487 (475-499) ng g^{-1} DW, respectively. Lower PAH levels were determined in the underlying marine sediments. In the surface sediments under the farms (0 m distance from the edge of the cages) and in the immediate vicinity, the concentration levels of n-alkanes and PAHs were significantly higher than in the surrounding sediments in both sites. PAHs and n-alkanes individual component profiles of fish feed and sinking material were similar with the corresponding profiles of the sediment samples collected in the immediate vicinity around the cages. On a daily basis, the average PAH sedimentation fluxes under the cages was 24.4 μg m^{-2} d^{-1}, which is considerably higher compared with the observed PAH sedimentary fluxes in the open eastern Mediterranean. Our results imply that fish farming is a significant source of these persistent organic pollutants (POPs) in the marine environment and therefore a likely change in the scale of production might introduce new sources of environmental risk. Further work is required in order to develop an appropriate monitoring system for the sustainable development of the aquaculture sector.

Van Scoy, A.R., Lin, C.Y., Anderson, B.S., Philips, B.M., Martin, M.J., McCall, J., Todd, C.R., Crane, D., Sowby, M.L., Viant, M.R., and Tjeerdema, R.S. Metabolic responses produced by crude versus dispersed oil in Chinook salmon pre-smolts via NMR-based metabolomics. *Ecotoxicology and Environmental Safety* 73(5): 710-717, 2010.

Notes: Crude oil spills from tankers remain a serious threat along coastal California. Resource managers require information on the acute toxicity of treated and untreated oil, and their sublethal effects on wildlife. This investigation compared the toxic actions of the water-accommodated fraction (WAF) and the chemically-enhanced WAF (CEWAF; Corexit 9500) of Prudhoe Bay crude oil in pre-smolt Chinook salmon (*Oncorhynchus tshawytscha*) via nuclear magnetic resonance (NMR)-based metabolomics. Metabolite profiles from muscle samples, after 96 h exposures, were measured using 1D ^{1}H NMR and compared via principal component analysis. It was determined that both WAF and CEWAF produced similar profiles in which amino acids, lactate and ATP comprised the highest intensity signals. Overall, metabolic substrates and growth measurements did not show residual effects of short-term exposure on long-term development. In conclusion, the 96 h LC_{50}s indicate dispersant application significantly decreased hydrocarbon potency and identified metabolites may be bio-indicators of hydrocarbon stress from hydrocarbon exposure.

Blanc, A.M., Holland, L.G., Rice, S.D., and Kennedy, C.J. Anthropogenically sourced low concentration PAHS: *In situ* bioavailability to juvenile Pacific salmon. *Ecotoxicology and Environmental Safety* 73(5): 849-857, 2010.

Notes: Gill 7-ethoxyresorufin O-deethylase (EROD) activity of juvenile Chinook salmon caged in Auke Lake, AK was used as a biomarker of polycyclic aromatic hydrocarbon (PAH) exposure. Biomarker measurements in conjunction with a

comprehensive sampling program that included grab water and sediment samples, and passive sampling devices were used to determine PAH concentrations, source(s), bioavailability, and resulting biological response. PAHs were detected at all lake locations except the reference site upstream of anthropogenic activity. Water samples were the best predictor of a biological response and EROD activity correlated to corresponding parts per trillion water pyrene concentrations (r^2=0.9662; p=0.0004). Sediment samples yielded the clearest indication of PAH sources and amalgamated contaminant magnitude, and passive samplers served as accumulators of retrospective aqueous conditions. Results suggest that salmon stocks are being exposed to chronic low-concentrations of anthropogenically sourced PAHs during sensitive life-stages, which may be in part a contributor to their declining numbers.

Carls, M.G. and Thedinga, J.F. Exposure of pink salmon embryos to dissolved polynuclear aromatic hydrocarbons delays development, prolonging vulnerability to mechanical damage. *Marine Environmental Research* 69(5): 318-325, 2010.

Notes: Exposure to dissolved polynuclear aromatic hydrocarbons (PAHs) from crude oil delays pink salmon (*Oncorhynchus gorbuscha*) embryo development, thus prolonging their susceptibility to mechanical damage (shock). Exposure also caused mortality, edema, and anemia consistent with previous studies. Hatching and yolk consumption were delayed, indicating the rate of embryonic development was slowed by PAH exposure. The net result was that exposed embryos were more susceptible to shock than normal, unexposed embryos. Susceptibility to shock was protracted by 4-6 d for more than a month in embryos exposed to exponentially declining, dissolved PAH concentrations in water passed through oiled rock; the initial total PAH concentration was 22.4 μg L^{-1} and the geometric mean concentration was 4 5 μg L^{-1} over the first 20 d. Protracted susceptibility to shock caused by exposure to PAHs dissolved from oil could potentially increase the reported incidence of mortality in oiled stream systems, such as those in Prince William Sound after the Exxon Valdez oil spill, if observers fail to discriminate between direct mortality and shock- induced mortality.

Nahrgang, J., Jonsson, M., and Camus, L. EROD activity in liver and gills of polar cod (*Boreogadus saida*) exposed to waterborne and dietary crude oil. *Marine Environmental Research* 70(1): 120-123, 2010.

Notes: Polar cod *Boreogadus saida* an indicator species for biomonitoring in the Arctic was exposed to crude oil in waterborne and dietary experiments. Ethoxyresorufin O-deethylase (EROD) activity was measured in liver and gills of polar cod at weeks 0, 2 and 4 of exposure and following 2 weeks of depuration. EROD increased significantly and dose-dependently in both tissues through both exposure routes. Levels were very low in gills compared to liver reflecting the tissue-specific metabolism capacities and tissue-specific response kinetics were also observed. Furthermore, a significant increase of gill EROD was shown in dietary exposed fish, demonstrating a substantial transport of PAHs via the systemic circulation. To conclude, this study gave some preliminary information on the EROD response in terms of levels, dose dependency and timing, in gills of PAH exposed polar cod.

Esler, D., Trust, K.A., Ballachey, B.E., Iverson, S.A., Lewis, T.L., Rizzolo, D.J., Mulcahy, D.M., Miles, A.K., Woodin, B.R., Stegeman, J.J., Henderson, J.D., and Wilson, B.W. Cytochrome P4501A biomarker indication of oil exposure in harlequin ducks up to 20 years after the Exxon Valdez oil spill. *Environmental Toxicology and Chemistry* 29(5): 1138-1145, 2010.

Notes: Hydrocarbon-inducible cytochrome P4501A (CYP1A) expression was measured, as ethoxyresorufin-O-deethylase (EROD) activity, in livers of wintering harlequin ducks (*Histrionicus histrionicus*) captured in areas of Prince William Sound, Alaska, USA, oiled by the 1989 Exxon Valdez spill and in birds from nearby unoiled areas, during 2005 to 2009 (up to 20 years following the spill). The present work repeated studies conducted in 1998 that demonstrated that in harlequin ducks using areas that received Exxon Valdez oil, EROD activity was elevated nearly a decade after the spill. The present findings strongly supported the conclusion that average levels of hepatic EROD activity were higher in clucks from oiled areas than those from unoiled areas during 2005 to 2009. This result was consistent across our sampling periods; furthermore, results generated from two independent laboratories using paired liver samples from one of the sampling periods were similar. The EROD activity did not vary in relation to age, sex, or body mass of individuals, nor did it vary strongly by season in birds collected early and late in the winter of 2006 to 2007. Indicating that these factors did not confound inferences about observed differences

between oiled and unoiled areas. We interpret these results to indicate that harlequin chicks continued to be exposed to residual Exxon Valdez oil up to 20 years after the original spill. This adds to a growing body of literature suggesting that oil spills have the potential to affect wildlife for much longer time frames than previously assumed.

McIntosh, S., King, T., Wu, D.M., and Hodson, P.V. Toxicity of dispersed weathered crude oil to early life stages of Atlantic herring (*Clupea harengus*). *Environmental Toxicology and Chemistry* 29(5): 1160-1167, 2010.

Notes: Reports of the chronic toxicity of dispersed crude oil to early life stages of fish perpetuate uncertainty about dispersant use. However, realistic exposures to dispersed oil in the water column are thought to be much briefer than exposures associated with chronic toxicity testing. To address this issue, the toxicity of dispersed weathered oil to early life stages of Atlantic herring (*Clupea harengus*) was tested for short exposure durations, ranging from 1 to 144h. Toxicity was a function of concentration and duration of exposure, as well as of the life stage exposed. Medium South American crude oil dispersed with Corexit 9500 caused blue sac disease in embryos, but not in free-swimming embryos. The age of embryos was negatively correlated with their sensitivity to oil; those freshly fertilized were most sensitive. Sensitivity increased after hatch, with free-swimming embryos showing signs of narcosis. Gametes were also tested; dispersed oil dramatically impaired fertilization success. For exposures of less than 24 h, gametes and free-swimming embryos were the most sensitive life stages. For those of more than 24 h, young embryos (<1 d old) were most sensitive. The results are presented as statistical models that could assist decisions about dispersant use in the vicinity of fish spawning habitats.

Zaborska, A., Mietelski, J. W., Carroll, J., Papucci, C., and Pempkowiak, J. Sources and distributions of ^{137}Cs, ^{238}Pu, ^{239,240}Pu radionuclides in the north-western Barents Sea. *Journal of Environmental Radioactivity* 101(4): 323-331, 2010.

Notes: Sediment deposits are the ultimate sink for anthropogenic radionuclides entering the marine environment. The major sources of anthropogenic radionuclides to the Barents Sea are fallout from nuclear weapons tests, long range transport from other seas, and river and non-point freshwater supplies. In this study we investigated activity concentrations, ratios, and inventories of the anthropogenic radionuclides, ^{137}Cs, ^{238}Pu, ^{239,240}Pu in dated sediment cores collected along a north-south transect in the northwestern Barents Sea. The data were used to evaluate the influence of different sources on the derived spatial and temporal patterns of anthropogenic radionuclides in seafloor sediment deposits. Activity concentrations of ^{137}Cs ranged from <0.1 Bq/kg to 10.5 Bq/kg while ^{239,240}Pu ranged from <0.01 Bq/kg to 2.74 Bq/kg and ^{238}Pu activity concentrations ranged from <0.01 Bq/kg to 0.22 Bq/kg. Total inventories of ^{137}Cs ranged from 29.5 ± 1.5 Bq/m^2 to 152.7 ± 5.6 Bq/m^2 and for ^{239,240}Pu inventories (6 sediment layers only) ranged from 9.5 ± 0.3 Bq/m^2 to 29.7 ± 0.4 Bq/m^2. Source contributions varied among stations and between the investigated radionuclides. The ^{238}Pu/^{239,240}Pu ratios up to 0.18 indicate discharges from nuclear fuel reprocessing plants as a main contributor of plutonium. Based on ^{238}Pu/^{239,240}Pu ratio, it was calculated that up to 19-27% of plutonium is supplied from sources other than atmospheric global fallout. Taking into account Atlantic current flow trajectories and that both activity concentrations and inventories of plutonium negatively correlate with latitude, Sellafield is a major source for the Barents Sea. Concentrations and inventories of ^{137}Cs correlate positively with latitude and negatively with distance from the Svalbard archipelago. The ^{137}Cs concentrations are highest in an area of intensive melting of sea ice formed along the Siberian coast. Thus, sea ice and supplies from Svalbard may be important source of ^{137}Cs to the Barents Sea seafloor.

Hu, Q.H., Weng, J.Q., and Wang, J.S. Sources of anthropogenic radionuclides in the environment: a review. *Journal of Environmental Radioactivity* 101(6): 426-437, 2010.

Notes: Studies of radionuclides in the environment have entered a new era with the renaissance of nuclear energy and associated fuel reprocessing, geological disposal of high-level nuclear wastes, and concerns about national security with respect to nuclear non-proliferation. This work presents an overview on sources of anthropogenic radionuclides in the environment, as well as a brief discussion of salient geochemical behavior of important radionuclides. We first discuss the following major anthropogenic sources and current developments that have lead, or could potentially contribute, to the radionuclide contamination of the environment: (1) nuclear weapons program; (2) nuclear weapons testing; (3) nuclear power plants; (4) uranium mining and milling; (5) commercial fuel reprocessing; (6) geological repository of high-level nuclear wastes that

include radionuclides might be released in the future, and (7) nuclear accidents. Then, we briefly summarize the inventory of radionuclides ^{99}Tc and ^{129}I, as well as geochemical behavior for radionuclides ^{99}Tc, ^{129}I, and ^{237}Np, because of their complex geochemical behavior, long half-lives, and presumably high mobility in the environment; biogeochemical cycling and environment risk assessment must take into account speciation of these redox-sensitive radionuclides.

Futch, J.C., Griffin, D.W., and Lipp, E.K. Human enteric viruses in groundwater indicate offshore transport of human sewage to coral reefs of the Upper Florida Keys. *Environmental Microbiology* 12(4): 964-974, 2010.

Notes: To address the issue of human sewage reaching corals along the main reef of the Florida Keys, samples were collected from surface water, ground-water and coral [surface mucopolysaccharide layers (SML)] along a 10 km transect near Key Largo, FL. Samples were collected semi-annually between July 2003 and September 2005 and processed for faecal indicator bacteria (faecal coliform bacteria, enterococci and *Clostridium perfringens*) and human-specific enteric viruses (enterovirus RNA and adenovirus DNA) by (RT)-nested polymerase chain reaction. Faecal indicator bacteria concentrations were generally higher nearshore and in the coral SML. Enteric viruses were evenly distributed across the transect stations. Adenoviruses were detected in 37 of 75 samples collected (49.3%) whereas enteroviruses were only found in 8 of 75 samples (10.7%). Both viruses were detected twice as frequently in coral compared with surface water or groundwater. Offshore, viruses were most likely to be found in groundwater, especially during the wet summer season. These data suggest that polluted groundwater may be moving to the outer reef environment in the Florida Keys.

Sutherland, K.P., Porter, J.W., Turner, J.W., Thomas, B.J., Looney, E.E., Luna, T.P., Meyers, M.K., Futch, J.C., and Lipp, E.K. Human sewage identified as likely source of white pox disease of the threatened Caribbean elkhorn coral, *Acropora palmata*. *Environmental Microbiology* 12(5): 1122-1131, 2010.

Notes: Caribbean elkhorn coral, *Acropora palmata*, has been decimated in recent years, resulting in the listing of this species as threatened under the United States Endangered Species Act. A major contributing factor in the decline of this iconic species is white pox disease. In 2002, we identified the faecal enterobacterium, *Serratia marcescens*, as an etiological agent for white pox. During outbreaks in 2003 a unique strain of *S. marcescens* was identified in both human sewage and white pox lesions. This strain (PDR60) was also identified from corallivorious snails (*Coralliophila abbreviata*), reef water, and two non-acroporid coral species, *Siderastrea siderea* and *Solenastrea bournoni*. Identification of PDR60 in sewage, diseased *Acropora palmata* and other reef invertebrates within a discrete time frame suggests a causal link between white pox and sewage contamination on reefs and supports the conclusion that humans are a likely source of this disease.

Gutleb, A.C., Cenijn, P., van Velzen, M., Lie, E., Ropstad, E., Skaare, J.U., Malmberg, T., Bergman, A., Gabrielsen, G.W., and Legler, J. In vitro assay shows that PCB metabolites completely saturate thyroid hormone transport capacity in blood of wild polar bears (*Ursus maritimus*). *Environmental Science and Technology* 44(8): 3149-3154, 2010.

Notes: Persistent chemicals accumulate in the arctic environment due to their chemical reactivity and physicochemical properties and polychlorinated biphenyls (PCBs) are the most concentrated pollutant class in polar bears (*Ursus maritimus*). Metabolism of PCB and polybrominated biphenyl ether (PBDE) flame-retardants alter their toxicological properties and these metabolites are known to interfere with the binding of thyroid hormone (TH) to transthyretin (TTR) in rodents and humans. In polar bear plasma samples no binding of [^{125}I]-T_4 to TTR was observed after incubation and PAGE separation. Incubation of the plasma samples with [^{14}C]-4-OH-CB107, a compound with a higher binding affinity to TTR than the endogenous ligand T_4 resulted in competitive binding as proven by the appearance of a radio labeled TTR peak in the gel. Plasma incubation with T_4 up to 1 mM, a concentration that is not physiologically relevant anymore did not result in any visible competition. These results give evidence that the binding sites on TTR for T_4 in wild living polar bears are completely saturated. Such saturation of binding sites can explain observed lowered levels of THs and could lead to contaminant transport into the developing fetus.

Kubota, A., Watanabe, M., Kunisue, T., Kim, E.-Y., Tanabe, S., and Iwata, H. Hepatic CYP1A induction by chlorinated dioxins and related compounds in the endangered black-footed albatross from the North Pacific. *Environmental Science and Technology* 44(9): 3559-3565, 2010.

Notes: The present study assesses effects of dioxins and related compounds (DRCs) including polychlorinated dibenzo-*p*-dioxins, polychlorinated dibenzofurans, and dioxin-like polychlorinated biphenyls (DL-PCBs) on cytochrome P450 1A (CYP1A) expression level in liver of black-footed albatrosses (*Phoebastria nigripes*) collected from the North Pacific. Total 2,3,7,8-tetrachloro-dibenzo-*p*-dioxin (2,3,7,8-T4CDD) toxic equivalents (TEQs) derived from toxic equivalency factor for birds proposed by World Health Organization were in the range of 2100 to 10 000 pg/g lipid wt (120-570 pg/g wet wt). Simultaneously, microsomal alkoxyresorufin *O*-dealkylase (AROD) activities, including methoxy-, ethoxy-, pentoxy-, and benzyloxy-resorufin *O*-dealkylase activities were also measured in the same specimens. Total TEQs and TEQ (on wet wt basis) from some individual DRC congeners had significant positive correlations with AROD activities, suggesting induction of CYP1A by DRCs. Congeners like 2,3,7,8-T4CDD and most of the DL-PCBs that showed no significant positive correlations between the concentrations and AROD activities, exhibited significant negative correlations between AROD activities and the concentration ratio of the congener to a recalcitrant CB169, suggesting preferential metabolism of these congeners by induced CYP1A. As far as we know, this is the first direct evidence revealing that hepatic CYP1A level is elevated with the accumulation of DRCs in the wild black-footed albatross population. The present study gives more robust estimate of impacts of DRCs on CYP1A induction in this rare pelagic species than indexes like hazard quotient and TEQ-threshold comparison that have been so far carried out.

Gilardi, K.V.K., Carlson-Bremer, D., June, J.A., Antonelis, K., Broadhurst, G., and Cowan, T. Marine species mortality in derelict fishing nets in Puget Sound, WA and the cost/benefits of derelict net removal. *Marine Pollution Bulletin* 60(3): 376-382, 2010.

Notes: Derelict fishing gear persists for decades and impacts marine species and underwater habitats. Agencies and organizations are removing significant amounts of derelict gear from marine waters in the United States. Using data collected from repeated survey dives on derelict gillnets in Puget Sound, Washington, we estimated the daily catch rate of a given derelict gillnet, and developed a model to predict expected total mortality caused by a given net based on entanglement data collected upon its removal. We also generated a cost:benefit ratio for derelict gear removal utilizing known true costs compared to known market values of the resources benefiting from derelict gear removal. For one study net, we calculated 4368 crab entangled during the impact lifetime of the net, at a loss of $19,656 of Dungeness crab to the commercial fishery, compared to $1358 in costs to remove a given gillnet, yielding a cost:benefit ratio of 1:14.5.

Jonsson, H., Sundt, R.C., Aas, E., and Sanni, S. The Arctic is no longer put on ice: Evaluation of polar cod (*Boreogadus saida*) as a monitoring species of oil pollution in cold waters. *Marine Pollution Bulletin* 60(3): 390-395, 2010.

Notes: The withdrawing Arctic ice edge will facilitate future sea transport and exploration activities in the area, which calls for the establishment of relevant cold water monitoring species. The present study presents first results of field baseline levels for core oil pollution biomarkers in polar cod (*Boreogadus saida*) sampled from pristine, Arctic waters. Furthermore, biomarker response levels were characterized in controlled laboratory exposure experiments running over 2 weeks. Fish exposed to a simulated petrogenic spill (1 ppm dispersed, crude oil) exhibited elevated hepatic EROD activity, bile PAH-metabolites, and hepatic DNA-adducts, whereas male individuals exposed to simulated produced water (30 ppb nonylphenol) exhibited a strong induction of plasma vitellogenin. In conclusion, the results demonstrated low and robust biomarker baseline levels that were clearly different from exposure responses. In combination with its high abundance and circumpolar distribution, the polar cod seems well qualified for oil pollution monitoring in Arctic waters.

Wise, J.P., Goodale, B.C., Wise, S.S., Craig, G.A., Pongan, A.F., Walter, R.B., Thompson, W.D., Ng, A.K., Aboueissa, A.M., Mitani, H., Spalding, M.J., and Mason, M.D. Silver nanospheres are cytotoxic and genotoxic to fish cells. *Aquatic Toxicology* 97(1): 34-41, 2010.

Notes: Nanoparticles are being widely investigated for a range of applications due to their unique physical properties. For example, silver nanoparticles are used in commercial products for their antibacterial and antifungal properties. Some of these products are likely to result in silver nanoparticles reaching the aquatic environment. As such, nanoparticles pose a health concern for humans and aquatic species. We used a medaka (*Oryzias latipes*) cell line to investigate the cytotoxicity and genotoxicity of 30 nm diameter silver nanospheres. Treatments of 0.05, 0.3, 0.5, 3 and 5 μg/cm^2 induced 80, 45.7, 24.3, 1 and 0.1% survival, respectively, in a colony forming assay. Silver nanoparticles also induced chromosomal aberrations and aneuploidy. Treatments of 0, 0.05, 0.1 and 0.3 μg/cm^2 induced damage in 8, 10.8, 16 and 15.8% of metaphases and 10.8, 15.6, 24 and 24 total aberrations in 100 metaphases, respectively. These data show that silver nanoparticles are cytotoxic and genotoxic to fish cells.

Bielmyer, G.K., Grosell, M., Bhagooli, R., Baker, A.C., Langdon, C., Gillette, P., and Capo, T.R. Differential effects of copper on three species of scleractinian corals and their algal symbionts (*Symbiodinium* spp.). *Aquatic Toxicology* 97(2): 125-133, 2010.

Notes: Land-based sources of pollution have been identified as significant stressors linked to the widespread declines of coral cover in coastal reef ecosystems over the last 30 years. Metal contaminants, although noted as a concern, have not been closely monitored in these sensitive ecosystems, nor have their potential impacts on coral-algal symbioses been characterized. In this study, three species of laboratory-reared scleractinian corals, *Acropora cervicornis*, *Pocillopora damicornis*, and *Montastraea faveolata* each containing different algal symbionts (*Symbiodinium* A3, C1 and D1a, respectively) were exposed to copper (ranging from 2 to 20 μg/L) for 5 weeks. At the end of the exposure period, copper had accumulated in the endosymbiotic dinoflagellate ("zooxanthellae") and animal tissue of *A. cervicornis* and the animal tissue of *M. faveolata*; however, no copper accumulation was detected in the zooxanthellae or animal tissue of *P. damicornis*. The three coral species exhibited significantly different sensitivities to copper, with effects occurring in *A. cervicornis* and *P. damicornis* at copper concentrations as low as 4 μg/L Copper exposure affected zooxanthellae photosynthesis in *A. cervicornis* and *P. damicornis*, and carbonic anhydrase was significantly decreased in *A. cervicornis* and *M. faveolata*. Likewise, significant decreases in skeletal growth were observed in *A. cervicornis* and *P. damicornis* after copper exposure. Based on preliminary results, no changes in *Symbiodinium* communities were apparent in response to increasing copper concentration. These results indicate that the relationships between physiological/ toxicological endpoints and copper accumulation between coral species differ, suggesting different mechanisms of toxicity and/or susceptibility. This may be driven, in part, by differences in the algal symbiont communities of the coral species in question.

Carrera-Martínez, D., Mateos-Sanz, A., López-Rodas, V., and Costas, E. Microalgae response to petroleum spill: An experimental model analysing physiological and genetic response of *Dunaliella tertiolecta* (Chlorophyceae) to oil samples from the tanker *Prestige*. *Aquatic Toxicology* 97(2): 151-159, 2010.

Notes: In November 2002, the oil tanker *Prestige* sank off the northwestern coast of Spain, spilling more than 50,000 tons of petroleum with disastrous ecological and economical consequences. In order to analyse the harmful consequences of the oil spill on marine microalgae, short- and long-term effects of oil samples from the *Prestige* spill were studied using laboratory cultures of *Dunaliella tertiolecta* (strain Dt1Lwt). Significant inhibition of photosynthesis (assessed by F_v/F_m, ETR_{max} and α estimations) was observed after only 1 h of oil exposure with clear concentration dependency. Three days later, photosynthetic activity remained inhibited although cell survival was only slightly effected. In cultures exposed to the lowest oil concentration, mitotic rates and percentage of motile cells were 17-33% and 12-42% of the controls, respectively. After 1 month, neither dividing nor motile cells were observed at the highest oil concentrations. However, after further incubation, occasionally the growth of rare cells resistant to oil was found. A fluctuation analysis was carried out to distinguish between resistant cells arising from rare spontaneous mutations and resistant cells arising from physiological or other mechanisms of adaptation. The existence of rapid evolution as result of preselective mutations from petroleum sensitivity to petroleum resistance was

observed. Resistant cells arose by rare spontaneous mutations prior to the addition of oil, with a mutation rate of 2.76 x 10^{-5} oil-resistant mutants per cell division. Apparently, rare spontaneous preselective mutations are able to assure the survival of microalgae in oil-polluted environments.

Bado-Nilles, A., Renault, T., Faury, N., Le Floch, S., Quentel, C., Auffret, M., and Thomas-Guyon, H. In vivo effects of LCO soluble fraction on immune-related functions and gene transcription in the Pacific oyster, *Crassostrea gigas* (Thunberg). *Aquatic Toxicology* 97(3): 196-203, 2010.

Notes: The effects of a soluble fraction of light cycle oil (LCO) on haemocyte parameters, phenoloxidase (PO) activity and mRNA expression of immune-related genes, in the Pacific oyster, *Crassostrea gigas*, were tested after seven days of exposure and two weeks of recovery period. Five polycyclic aromatic hydrocarbons (PAHs) out of ten detected in tank water had bioaccumulated at the end of the contamination period. The concentration of PAHs in oyster tissues decreased during the recovery period and 14 days after the exposure, 69% of bioaccumulated PAHs were detected in contaminated oysters. The exposure induced severe oyster mortality (21%), external and internal green colouration of the shell and a significant decrease of PO activity. The mRNA expression of several genes was altered. As a conclusion, a modulation of immune-related parameters was demonstrated using three different approaches, namely cellular (flow cytometry), biochemical (spectro-photometry) and genomics (gene transcription) in oysters after contact with soluble fraction of LCO.

Nahrgang, J., Camus, L., Carls, M.G., Gonzalez, P., Jönsson, M., Taban, I.C., Bechmann, R.K., Christiansen, J.S., and Hop, H. Biomarker responses in polar cod (*Boreogadus saida*) exposed to the water soluble fraction of crude oil. *Aquatic Toxicology* 97(3): 234-242, 2010.

Notes: In order to mimic the biological effects of an oil spill in Arctic waters, we examined several types of biomarkers (genes, enzymes, metabolites, and DNA damage) in polar cod *Boreogadus saida* experimentally exposed to the water soluble fractions of crude oil. During 4 weeks of exposure, induction of the studied biomarkers exceeded baseline levels. The mRNA expression of the cytochrome P4501A1 (*cyp1a1*) gene was the most promising biomarker, with glutathione S-transferase (*gst*) as a suitable complement. The delayed ethoxyresorufin O-deethylase (EROD) and GST activities and their persistence following 2 weeks of depuration may allow detection of previous exposures in field samples. The composition of PAH metabolites in the bile indicated the bioavailability of different PAH size-classes. Although mRNA expressions of antioxidant defense genes were induced at start of the exposure, with the strongest responses from catalase and cytosolic superoxide dismutase, they were poor for oil monitoring purposes due to their very short response times. Significant DNA damage demonstrated genotoxicity even at low PAH concentrations (<15 μg L^{-1}) and was correlated with benzo(*a*)pyrene and pyrene metabolites in the bile.

Claireaux, G. and Davoodi, F. Effect of exposure to petroleum hydrocarbons upon cardio-respiratory function in the common sole (*Solea solea*). *Aquatic Toxicology* 98(2): 113-119, 2010.

Notes: The long term consequences of oil exposure upon marine populations are still poorly evaluated. One particular missing piece of information relates to the link between oil exposure, individuals' ability to face environmental contingencies and populations' production and dynamics. In that context, the present paper investigates the impact of oil exposure upon fish cardio-respiratory performance, this performance being viewed as a key determinant of individual fitness. Experimental conditions replicated the contamination conditions observed during the weeks that immediately followed the *Erika* oil spill (west coast of France; December 1999). Sole (*Solea solea*) were exposed to number-2 oil for 5 days and were then challenged with an acute rise in temperature (from 15 to 30 ºC at 1.5 ºC h^{-1}). Oxygen consumption, cardiac output, heart rate and stroke volume were monitored throughout. Experimental results showed that compared to uncontaminated control animals, oil-exposed sole displayed impaired cardio-respiratory responses and were unable to meet the temperature-driven increase in tissues oxygen demand. The relationship between oxygen consumption and cardiac output indicated that oil-exposed fish had recourse to venous oxygen stores very early in the thermal challenge (20 ºC). In control fish there was no evidence for depletion of venous oxygen store until above 25 ºC.

Bilbao, E., Raingeard, D., Diaz de Cerio, O., Ortiz-Zarragoitia, M., Ruiz, P., Izagirre, U., Orbea, A., Marigómez, I., Cajaraville, M.P., and Cancio, I. Effects of exposure to *Prestige*-like heavy fuel oil and to perfluorooctane sulfonate on conventional biomarkers and target gene transcription in the thicklip grey mullet *Chelon labrosus*. *Aquatic Toxicology* 98(3): 282-296, 2010.

Notes: Thicklip grey mullets *Chelon labrosus* inhabit coastal and estuarine areas where they can be chronically exposed to commonly released pollutants such as polycyclic aromatic hydrocarbons (PAHs) and perfluorinated compounds. These pollutants can also originate from accidental spills, such as the *Prestige* oil spill in 2002, which resulted in the release of a heavy fuel oil that affected coastal ecosystems in the Bay of Biscay. Peroxisome proliferation (PP), induced biotransformation metabolism, immunosuppression and endocrine disruption are some of the possible biological effects caused by such chemicals. With the aim of studying the effects of organic toxic chemicals on such biological processes at the transcriptional and at the cell/tissue level, juvenile mullets were exposed to the typical mammalian peroxisome proliferator perfluorooctane sulfonate (PFOS), and to fresh (F) and weathered (WF) Prestige-like heavy fuel oil for 2 and 16 days. First, fragments of genes relevant to biotransformation, immune/inflammatory and endocrine disruption processes were cloned using degenerate primers. Fuel oil elicited a significant PP response as proved by the transcriptional upregulation of *palmitoyl-CoA oxidase* (*aox1*), *peroxisome proliferator activated receptor α* (*pparα*) and *retinoic X receptor*, by the AOX1 activity induction and by the increased peroxisomal volume density. PFOS only elicited a significant induction of AOX1 activity at day 2 and of PPARα mRNA expression at day 16. All treatments significantly increased catalase mRNA expression at day 16 in liver and at day 2 in gill. *Cyp1a* transcription (liver and gill) and EROD activity were induced in fuel oil treated organisms. In the case of phase II metabolism only hepatic glutathione S-transferase mRNA was overexpressed in mullets exposed to WF for 16 days. Functionally, this response was reflected in a significant accumulation of bile PAH metabolites. WF treated fish accumulated mainly high molecular weight metabolites while F exposure resulted in accumulation of mainly low molecular ones. Fuel oil significantly regulated immune response related *complement component C3* and *hepcidin* transcription followed by a significant regulation of inflammatory response related apolipoprotein-M and fatty acid binding protein mRNAs at day 16. These responses were accompanied by a significant hepatic inflammatory response with lymphocyte accumulations (IRLA) and accumulation of melanomacrophage centers (MMC). PFOS did not elicit any transcriptional response in the studied biotransformation and immune related genes, although histologically significant effects were recorded in IRLA and MMC. A significant reduction of lysosomal membrane stability was observed in all exposed animals. No endocrine disruption effects were observed in liver while brain aromatase mRNA was overexpressed after all treatments at day 2 and *estrogen receptor* a was downregulated under WF exposure at day 16. These results show new molecular and cellular biomarkers of exposure to organic chemicals and demonstrate that in mullets PP could be regulated through molecular mechanisms similar to those in rodents, although the typical mammalian peroxisome proliferator PFOS and heavy fuel oil follow divergent mechanisms of action.

Hatlen, K., Sloan, C.A., Burrows, D.G., Collier, T.K., Scholz, N.L., and Incardona, J.P. Natural sunlight and residual fuel oils are an acutely lethal combination for fish embryos. *Aquatic Toxicology* 99(1): 56-64, 2010.

Notes: The majority of studies characterizing the mechanisms of oil toxicity in fish embryos and larvae have focused largely on unrefined crude oil. Few studies have addressed the toxicity of modern bunker fuels, which contain residual oils that are the highly processed and chemically distinct remains of the crude oil refinement process. Here we use zebrafish embryos to investigate potential toxicological differences between unrefined crude and residual fuel oils, and test the effects of sunlight as an additional stressor. Using mechanically dispersed oil preparations, the embryotoxicity of two bunker oils was compared to a standard crude oil from the Alaska North Slope. In the absence of sunlight, all three oils produced the stereotypical cardiac toxicity that has been linked to the fraction of tricyclic aromatic compounds in an oil mixture. However, the cardiotoxicity of bunker oils did not correlate strictly with the concentrations of tricyclic compounds. Moreover, when embryos were sequentially exposed to oil and natural sunlight, the bunker oils produced a rapid onset cell-lethal toxicity not observed with crude oil. To investigate the chemical basis of this differential toxicity, a GC/MS full scan analysis was used to identify a range of compounds that were enriched in the bunker oils. The much higher phototoxic potential of chemically distinct bunker oils observed here suggests that this mode of action should be considered in the assessment of bunker oil spill impacts, and indicates the need for a broader approach to understanding the aquatic toxicity of different oils.