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Novel methods, new results and science-based solutions to tackle marine debris impacts on wildlife

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ABSTRACT

There is an exponentially increasing amount of human-associated litter in our oceans. This marine litter results in a wide range of potential impacts on the environment. These range from the introduction of adsorbed polychlorinated biphenyls (PCBs) into food webs to the entanglement and subsequent mortality of threatened seabirds, fish, turtles and mammals in anthropogenic litter and derelict fishing gear. While there has been a major effort afoot to publicize these issues, there remains a paucity of data and scientific research to underpin solutions to the problems. To address knowledge gaps and to identify potential solutions, we assembled thirteen experts from around the world who are leaders in the field. Speakers present current research in three major areas: 1) integrated ecological and oceanographic models to that measure risk to wildlife and predict impact, 2) literature reviews and field studies that measure both the scope and intensity of the threat across species, and 3) analysis of wildlife indicators as regulatory standards for plastic concentration in the environment.

1. Background

Marine litter is an environmental, economic, human health and aesthetic problem. It results in economic losses in excess of hundreds of millions of dollars annually. These losses are associated with reduced tourism revenues, vessel damage, impairments in marine environments, invasives species transport and damage to public health. They also include negative impacts on recreational activities including beach going and fishing. Coastal and marine litter poses a growing threat to marine biodiversity (Vegter et al., 2014), with increasing reports of impacts to individuals, populations, species and ecosystems in the world's oceans and along our shorelines. It poses a complex challenge that has significant implications for marine and coastal environments and human activities around the world.

Most of the litter that ends up in our ocean is lightweight, durable, strong, inexpensive and long-lasting plastic. Annual global production of plastic has risen from 1.5 million tonnes in the 1950s, to 288 million tonnes in 2012; and it is presently doubling approximately every eleven years (PlasticsEurope, 2013). More than six million metric tons of plastic is estimated to enter the ocean each year from land-based sources and this is predicted to increase by an order of magnitude in the next ten years (Jambeck et al., 2015). The total degradation time for plastics in particular is unknown, with estimates in the hundreds of years for many types of consumer products. Thus, litter in the marine environment is a multi-generational problem that extends far beyond the lifespan of the current human population.

To understand the state of knowledge and gain insights into a broad range of ecological impacts resulting from anthropogenic litter, we invited speakers from around the globe to present their latest findings in a symposium that focused on marine debris impacts on wildlife. The symposium featured thirteen speakers who shared results from emerging work on a suite of marine debris research topics, from ingestion and entanglement to the demonstrated chemical impacts of debris. The work presented ranged from a recent literature review that summarized the state of knowledge to multiple risk analysis approaches, including expert elicitation, experimental studies, and risk modelling. Recent research was also presented that focused on threats posed by debris to focal taxa (turtles, seabirds and marine mammals) and evaluated the efficacy and influence of waste management policies on coastal debris. Researchers also shared findings on approaches to monitoring marine debris at sea, the density of marine litter on

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seamounts, and derelict gear impacts on marine fauna. Species and fisheries-specific examples highlighted some success stories and monitoring approaches that achieve ecological quality targets and reduce impacts to biodiversity through implementation of litter and gear removal efforts.

2. Problem scope, risk framework and risk assessments for protected species

Just over a decade ago, the number of marine species known to be impacted by anthropogenic litter was estimated at around 260 species (Derraik, 2002). Now, the number of marine species with reports of fatal entanglement in and ingestion of marine debris has risen to nearly 700, and continues to increase (Gall and Thompson, 2015). A recent review of 340 publications on encounters and impacts between marine debris and marine animals described the current state of knowledge on the effects of anthropogenic debris on marine and coastal species (updated from STAP, 2011; Secretariat of the Convention on Biological Diversity and the Scientific Advisory Panel – GEF, 2012). Plastic debris accounted for over 90% of encounters between debris and wildlife, with microplastics (defined as items <5 mm) noted in 10% of ingestion reports. Both indirect and direct consequences of wildlife-debris encounters are increasing, though there is still little published information on population-level and/or sub-lethal consequences of debris interaction (but see Rochman et al., 2013, 2014a,b; this paper). While direct harm or death has been reported for far more entanglement encounters (79%) than ingestion encounters (4%), ingestion may pose substantial lethal and sub-lethal impacts for individuals. Furthermore, a minimum estimate of 17% of species on the IUCN Red List known to known to encounter debris either via entanglement, ingestion or both are currently listed as threatened or near-threatened. This work has since been further updated, with 340 original publications reporting encounters between debris and individuals for 693 species (Gall and Thompson, 2015).

As we see an increase in marine species interacting with wildlife, identifying the potential impacts of litter on major marine taxa provides a potentially useful lever for change. From more than 200 million debris items removed and identified over nearly 30 years of International Coastal Cleanup events, the most common 20 litter items in Ocean Conservancy's global database have been identified. Expert elicitation was used to assess the relative ecological threat or risk each of these litter items poses to animals in the marine environment. More than 80 respondents from sectors ranging from scientific organizations and non-governmental organizations to volunteers assessed the entanglement, physical ingestion and chemical contamination threat that each of the top 20 debris items poses to seabirds, turtles and marine mammals. Experts rated fishing nets and gear, balloons, plastic bags, plastic beverage bottle caps, and plastic utensils as the litter items most harmful to wildlife. The results provide support for the implementation of plastic bag bans and bottle deposits that are already underway in some areas. The findings also provide a means of identifying those items that experts rank as litter that is most likely to result in harm to key marine taxa. However, the need to implement large-scale solutions to reduce the input of plastic litter into the marine environment cannot be overlooked.

Another means of evaluating the risk anthropogenic litter poses to wildlife is to combine empirical data and models to predict areas of risk to marine taxa. Scientists have been applying a risk framework to predict the scale and extent of risk to seabirds and turtles at both regional and global scales (Schuyler et al., 2013; Wilcox et al., 2014; Wilcox et al. submitted for publication). To understand the threat marine debris poses to wildlife, researchers combined published literature with empirical information and modelling to predict the highest areas of risk for nearly 200 of the world's seabird species. A global-scale particle-tracking model was used to predict the distribution of floating litter in the ocean, based upon coastal human population density around the world (sensu van Sebille et al., 2012). The oceanic litter distribution was then overlaid with the distribution of seabird taxa to evaluate the exposure of each species to debris, based upon spatial overlap between marine litter and individual seabird species. Comparing estimates of exposure to published seabird diet studies provided an empirical comparison to allow evaluation of the reliability of exposure as a predictor of debris ingestion. While exposure to plastic was a significant predictor of debris ingestion, body size and foraging strategy are also important predictors. Based upon empirical evidence and model predictions, areas of highest risk are not in the northern hemisphere's gyres as may be predicted based upon litter density and the awareness of ocean 'garbage patches', but instead are along the northern boundary of the southern ocean where seabird species richness is particularly high.Approach can be used to provide a hierarchical list of species likely to be heavily impacted based on their ecological characteristics, along with a global map of expected impacts from various anthropogenic stressors.

Following on the risk framework approach used to evaluate threats to seabirds, researchers applied a global risk model to identify the factors that are most influential in determining the probability of a sea turtle ingesting debris. The model used incorporated debris distribution maps based on ocean drifter data, sea turtle habitat maps, and field necropsies for validation. It also used multiple measures of debris encounter rates, life history stage, species of turtle, and date of stranding. Life history stage was the best predictor of debris ingestion (young oceanic turtles are more likely to ingest debris than are older coastal feeding turtles), but the best-fit model also incorporated the species and plastic exposure within a limited distance (250 km) and time from stranding observation (one year). Olive ridley turtles (Lepidochelys olivacea) are at the highest risk of debris ingestion and Kemp's ridley turtles (Lepidochelys kempii) are at the lowest risk of debris ingestion. In contrast to findings of turtle entanglement risk, encounter rates between turtles and debris is not the sole predictor of debris ingestion, suggesting that selectivity plays a more important role in ingestion rates than entanglement rates. Importantly, ingestion rates for sea turtles have increased significantly through time, with increased rates of plastics ingestion reported in some species of sea turtles in particular (e.g. green and leatherbacks [*Chelonas mydas* and *Dermochyls coriacea*, respectively]; see Schuyler et al., 2012, 2013).

While debris is often reported from along our coastlines and floating on the ocean's surface, far less is known about the abundance and distribution of the debris that sinks to the ocean floor. To understand the full spatial extent over which we find human-made refuse, researchers have been exploring the deep sea (at 200 m and beyond). Remote cameras, aiming to document deep marine fauna, observed everything from 18th century clay pots to wine bottles, derelict fishing gear, electronics and plastic rubbish, at densities up to 17.4 items per hectare (Woodall et al.). Litter on the ocean floor was ubiquitous, but patchy and highly variable between seamounts. In the southwest Indian Ocean, derelict fishing gear was the most abundant type of litter observed. Skeletal remains of numerous species of wildlife were found with this derelict gear in the deep sea, implicating the gear as a potential mortality source. Similar to findings of coastal litter, plastic was the most common material type for items found during these deep sea surveys. This work demonstrates that the abundance, material type and most likely source of submerged litter is likely linked with local activities such as shipping and fishing.

In addition to contributing to the sunken litter found on seamounts and on the ocean floor, abandoned, lost and derelict fishing gear (ALDFG) results in significant economic losses to industry and causes environmental damage and death to marine fauna. Analyses of ghost fishing by derelict traps from multiple sites in the United States found that the abundance of derelict traps ranged from 5 to 47 traps per square kilometre and varied by fishery. Lost traps continued to ghost fish for months to years, ensnaring and unintentionally killing fish, turtles and marine mammals. Ghost fishing by derelict traps has a measurable effect on the annual catch harvests of target species and results in considerable economic losses in fisheries. Encouraging news included the opportunity for preventing the detrimental economic and environmental impacts through partnerships, policy implementation and enforcement (Arthur et al., 2014). Examples of successful programs to reduce ALDFG include the 'Fishing for Energy' program in which the fishing community is provided with no-cost options for gear disposal whereby nets, lines and rope are converted to energy (http://marinedebris.noaa.gov/partnerships/fishing-energy). Another example is the Oregon cooperative gear removal initiative supported by the Dungeness crab fishery and several state agencies (Arthur et al., 2014).

Recovering ALDFG from the marine environment restores underwater habitat, combats ghost fishing associated with that gear, can reduce costs to fishermen by recycling gear, and provides opportunities to examine impacts on marine wildlife. Since 2002, the Northwest Straits Marine Conservation Initiative in the USA has located and removed thousands of fishing nets lost over the last 50 years in the waters of Puget Sound and nearby straits. Building on previous reports (Good et al., 2010), analyses of over 4000 recovered derelict salmon gillnets documented mortality of hundreds of marine species, identified characteristics of derelict nets associated with mortality, and estimated their impacts on major marine taxa including mammals, birds, fish, and invertebrates. Derelict fishing nets in the Puget Sound area have killed >336,000 individuals of at least five marine mammal, 19 marine bird, 48 marine fish, and 175 marine invertebrate species, many of which are species of conservation concern. Net characteristics (*e.g.*, location, habitat, size, extent of suspension) influenced mortality patterns (presence/counts of animals; animals/m^2 of net) for the major taxa. Animals recorded during net recoveries provide a snapshot of their effects: extending these data using simulations based on animals killed over time and the time nets were derelict in the water suggested that ca. 4500 nets killed may have killed upwards of 2,500,000 marine invertebrates, 800,000 fish, and 20,000 marine birds prior to removal. There are hopeful signs from these efforts, however. The "population" of derelict nets estimated from net loss rates and fleet statistics over the past fifty years suggest that 80% of these legacy nets have been recovered (Antonelis, 2013). Their removal has restored almost 3,000,000 m^2 of benthic marine habitat. Moreover, legislation in Washington state now requires reporting lost gillnets, present-day net loss rates are low, and newly lost nets are rapidly recovered (J. Drinkwin Northwest Straits Foundation, pers. comm.). The methods and analyses used in Puget Sound are also exportable; modelling based on bathymetry and net depth at removal locations predicted hotspots for nets throughout Puget Sound and will be used to help prioritize removals of derelict gear in British Columbia (Antonelis, 2013).

In the Arafura and Timor Seas (ATS) separating Northern Australia from Southeast Asia, biodiversity impacts from derelict nets or ghost nets is also an important issue. Recent estimates suggest that between 5000 and 15,000 turtles have been killed by ghost nets in this region (Wilcox et al., 2014), demonstrating the severity of this anthropogenic threat to turtle populations. An analysis of nearly 3000 nets recovered at sea during the last fifteen years finds that 14% of nets have entangled animals in them, and half of these entanglements are turtles (Dethmers et al., unpubl.). Several species of turtles have been found entangled in these ghost nets, and there are multiple genetic stocks of turtles breeding and foraging in this shallow sea region. Combined, these issues mark the northern ATS region as a critical hotspot for turtle-ghost net interactions.

Studies of marine debris have typically focused on beach debris, as seen in cleanup efforts around the world (Ocean Conservancy and others). Recently, the ubiquity of micro plastic pollution at or near the ocean's surface has also been highlighted (sensu Cozar et al., 2014; Eriksen et al., 2014; Law et al., 2010). There remains, however, a knowledge gap in our understanding of the amount of surface floating macro debris in the marine environment, but for a few local or regional studies (see Day et al., 1990; Thiel et al., 2003; Pichel et al., 2007). One way to fill this knowledge gap is to collect systematic data on the presence, abundance and type of surface marine debris aboard ships of opportunity. Collecting surface macro debris data is possible during research cruises that focus on cetacean and bird surveys as well as during ocean transit voyages. Sharing data collection approaches will improve the utility of such monitoring measures, while providing much-needed quantitative data on macro debris in the marine environment. Such an approach fits in well with the European Marine Strategy Framework Directive (MSFD), which requires monitoring to detect trends in the composition, quantities and effects of marine litter.

Preceding the MFSD, the Oslo and Paris Conventions (OSPAR) initiated the development of a system of Ecological Quality Objectives (EcoQOs) which fixed monitoring approaches with associated targets for acceptable ecological quality. The northern fulmar (*Fulmaris glacialis*) became the key EcoQO indicator species for monitoring plastic debris in the North Sea, based upon the abundance of plastic debris that is ingested by this species. The EcoQO target defined for plastic pollution in North Sea is having less than 10% of fulmars with more than 0.1 g of plastic in the stomach, based on sampling beach-washed birds. Reaching those targets appears to be some way off, however, as the current of fulmars from the North Sea exceeding the 0.1 g limit is 60%. Only 5% of seabirds surveyed in the North Sea have no plastic in their stomachs, and the only locations where sampled stomachs approach the EcoQO target are in remote arctic environments (van Franeker et al., 2011, 2014).

Given the effectiveness of using focal marine species as indicators of environmental quality, the European Marine Strategy Framework Directive is also looking at other marine species such as loggerhead turtles (*Caretta caretta*) to act as environmental sentinels for ingested marine litter. The goal is for each member state to achieve or maintain 'Good Environmental Status' for the marine environment by 2020. Plastic ingestion rates by sea turtles appear to be a useful indicator, but the definition of an ecological quality objective is still needed, as well as research on alternative potential indicator species (Galgani et al., 2014). To evaluate the suitability of loggerheads to act as environmental indicator species, data were collected and analysed from stranding networks and rescue centres on the Atlantic and Mediterranean coasts of France as well as from turtle telemetry programmes and oceanographic cruises in the western Mediterranean Sea. Three EcoQO scenarios were proposed, taking into account biological constraints and habitat characteristics for loggerheads in the region. Using loggerhead turtles as a target species looks promising, and the EMSFD monitoring protocols are already being standardized. The use of single-species indicators of environmental health of marine ecosystems is proving useful and effective, as it resonates with the public, monitoring methods are straightforward and achievable, and, for wide-ranging species, considerable geographic breadth can be achieved.

Delving deeper into the impacts of plastic ingestion on wildlife,

Table 1
Symposium presenters/contributors, their affiliations, and presentation titles for the IMCC3 symposium "Novel methods, new results and science-based solutions to tackle marine debris impacts on wildlife." (Presenting author in **bold**; email for presenting author in *italics*). Presentations listed in the order in the symposium.

Impacts of anthropogenic debris on marine life.	Prof. R.C. Thompson, Marine Biology and Ecology Research Centre, Plymouth University; **Sarah C. Gall**, Marine Biology and Ecology Research Centre, Plymouth University; *sarah.gall@plymouth.ac.uk*
Prioritizing the threat of ocean debris in marine environments	**Nicholas Mallos**, Ocean Conservancy; A.G. Rodriguez, Ocean Conservancy; G.H. Leonard, Ocean Conservancy; *nmallos@oceanconservancy.org*
The influence and efficacy of waste management policies on coastal marine debris in Australia	**Dr. Britta Denise Hardesty**, CSIRO Oceans and Atmosphere Flagship, Hobart, Tasmania; T.J. Lawson, CSIRO Oceans and Atmosphere Flagship; C. Maureaud, CSIRO Oceans and Atmosphere Flagship; C. Wilcox, CSIRO Oceans and Atmosphere Flagship; *denise.hardesty@csiro.au*
Monitoring of marine debris; demonstrating the feasibility of collecting ancillary data on marine debris during boat based surveys and ocean passages	**Ms. Anna Cucknell**, Marine Conservation Research International, International Fund for Animal Welfare; O. Boisseau, Marine Conservation Research International, International Fund for Animal Welfare; C. Ryan, Marine Conservation Research International, International Fund for Animal Welfare; A. Moscrop, Marine Conservation Research International, International Fund for Animal Welfare; *acucknell@mcr-team.org*
Extreme litter picking: Comparison of litter across seamounts.	**Dr. Lucy C. Woodall**, Natural History Museum, London; A.D. Rogers, University of Oxford; M. Packer, Natural History Museum, London; L.F. Robinson, University of Bristol; B.E. Narayanaswamy, Scottish Association for Marine Sciences, Oban; G. Paterson, Natural History Museum, London; *l.woodall@nhm.ac.uk*
Trends and analysis of ghost-fishing by derelict traps in the coastal United States.	**Ms. Courtney Arthur**, U.S. National Oceanic and Atmospheric Administration and I.M. Systems Group; A. Sutton-Grier, U.S. National Oceanic and Atmospheric Administration; P. Murphy, U.S. National Oceanic and Atmospheric Administration; H. Bamford, U.S. National Oceanic and Atmospheric Administration; *courtney.arthur@noaa.gov*
Deadliest bycatch: estimating the impacts of derelict salmon gillnets on marine wildlife	**Dr. Thomas P. Good**, Conservation Biology Division, Northwest Fisheries Science Center, NOAA Fisheries/NMFS; E.J. Ward, Conservation Biology Division, Northwest Fisheries Science Center, NOAA Fisheries/NMFS; K. Antonelis, Natural Resources Consultants, Inc.; *tom.good@noaa.gov*
A global risk assessment for marine debris impacts on seabirds.	**Dr. Chris Wilcox**, CSIRO Oceans and Atmosphere Flagship, Hobart, Tasmania; B.D. Hardesty, CSIRO Oceans and Atmosphere Flagship; E. van Sebille, Climate Change Research Centre & ARC Centre of Excellence for Climate System Science, University of New South Wales, Australia; *chris.wilcox@csiro.au*
The OSPAR Ecological Quality Objective on plastics ingested by fulmars.	**Dr. Jan A. Van Franeker**, Institute for Marine Resources and Ecosystem Studies (IMARES), The SNS Fulmar Study Group c/o IMARES, Wageningen UR; *jan.vanfraneker@wur.nl*
Modelling the risks of debris ingestion by endangered species: a sea turtle case study.	**Dr. Qamar A. Schuyler**, University of Queensland; C. Wilcox, CSIRO Oceans and Atmosphere Flagship; K. Wedemeyer, Texas A&M University; G. Balazs, Pacific Islands Fisheries Science Center; E. van Sebille, University of New South Wales; B.D. Hardesty, CSIRO Oceans and Atmosphere Flagship; *q.schuyler@uq.edu.au*
Caught in ghost nets; identifying a way to reduce mortality of regionally endangered sea turtle populations.	**Dr. Kiki E.M. Dethmers**, North Australia Marine Research Alliance (NAMRA); I.B.W. Adnyana, Udayana University, Denpasar, Indonesia; C.J. Limpus, Department of Environment and Heritage Protection, Brisbane; D.K. Williams, Australian Institute of Marine Science (AIMS); N.N. FitzSimmons, Griffith University, Queensland; J.S. Keogh, The Australian National University, Canberra; S.D. Whiting, Department of Parks and Wildlife, Kensington; *kiki.dethmers@cdu.edu.au*
Scientific basis for an ecological quality objective in sea turtles within the Marine Strategy Framework Directive.	G. Darmon, aux-Facultés, 34090 Montpellier, France Centre d'Ecologie Fonctionnelle et Evolutive-Centre National de la Recherche Scientifique (CEFE-CNRS), Montpellier, France; C. Miaud, CEFE-CNRS, Montpellier, France; D. Gambaiani, Centre d'Etudes et de Sauvegarde des Tortues Marines de Méditerranée (CESTMED), seaquarium du Grau du Roy, France; F. Dell'Amico, Centre d'études et de soins pour les tortues marines (CESTM)/Aquarium de La Rochelle, France; F. Claro, Muséum National d'Histoire Naturelle (MNHN), France; **Francois Galgani**, Institut Français de Recherche pour L'exploitation de la Mer (IFREMER), Laboratoire Environnement Ressources/Provence Azur Corse, Bastia, France; *francois.galgani@ifremer.fr*
Plastics and priority pollutants: a multiple stressor in aquatic habitats	**Dr. Chelsea M. Rochman,** U.C. Davis; E. Hoh, San Diego State University; R.L. Lewison, San Diego State University; T. Kurobe, U.C. Davis; S.J. Teh, U.C. Davis; *cmrochman@ucdavis.edu*

new research highlighted some of the first work demonstrating that plastic debris transfers hazardous chemicals to aquatic organisms and can function as a multiple stressor, leading to adverse health effects from the plastic debris and the mixture of chemicals. Laboratory experiments using a model fish species, Japanese medaka (*Oryzias latipes*), measured chemical transfer and toxicity from plastic ingestion, including effects at molecular, cellular and tissue levels. After a laboratory dietary exposure, fish were exposed to a mixture of plastic + pollutants, fish had significantly greater concentrations of polybrominated diphenyl ethers (PBDEs) in their tissues, demonstrating the bioaccumulation of persistent organic pollutants (POPs) as a result of plastic ingestion. Fish also showed signs of gonadal and liver toxicity and pathology from both plastic pollutants and the virgin polyethylene itself, suggesting that future assessments should consider the complex mixture of plastic and pollutants (Rochman et al., 2013, 2014a). Moreover, results from a field study found a positive relationship between plastic density and concentrations of PBDEs in the tissue of mesopelagic fish sampled from the South Atlantic (Rochman et al., 2014b). These field data provide a key demonstration that bioaccumulation/sorption observed in the laboratory also occurs in nature, as has also recently been shown in mussels and lugworms (Cauwenberghe et al., 2015). Demonstrating the desorption of plastic contaminants in the digestive systems of marine fauna is still in the early stages; however, such novel research provides some of the first evidence of how plastic debris may act as a vector of hazardous pollutants in marine food webs.

In order to address the sources of plastic pollution before it enters the marine environment and ensnares or is ingested by wildlife, it is worth focussing on efforts to identify land-based sources and evaluate the effectiveness of various waste management policies. To evaluate the influence and efficacy of local waste management policies on coastal marine debris, scientists in Australia carried out a rigorous national coastal debris survey every 100 km around the continent to quantify the density, types, and potential sources of marine debris. One of the goals was to understand potential drivers of debris hotspots and to determine the efficacy of waste management policies on coastal marine debris. Accordingly, to accompany litter surveys on the coastline, interviews were conducted at the local council level to determine waste management policies in >40 regions around the country. Interviews focused on representation of councils geographically placed within areas where coastal debris surveys took place within each state/territory where higher or lower concentrations of litter were observed. Waste management legislation and policies were evaluated to look at correlations between resources, population density, coastline length and quantity and types of debris observed on beaches and waste policies (such as bins, recycling, river waste traps, waste facilities, etc.) that were in place within the regions sampled. Results pointed to the effectiveness of recycling programs as well as anti-dumping and anti-litter campaigns (e.g. increased public awareness). These activities were more important than the total dollar amount spent on waste management facilities within the regions surveyed, though waste bins at coastal sites also correlated with less litter on beaches. Findings from this work can be used to implement cost effective strategies aimed at reducing litter inputs to the marine environment (Hardesty et al., 2014).

3. Conclusions

Research into the types, amounts, sources and impacts of marine litter is on the rise, as is the rate of global production of plastic. Science is critical to understanding the sources, fates, and impacts of marine debris, the strategies for reducing inputs of marine debris and litter into the marine environment, and to inform policy and decision makers. Also important is effective communication of scientific findings to a public that can be responsive when presented with clearly articulated findings, future scenarios, and effective management strategies and opportunities. Despite research that has documented the ubiquity of anthropogenic litter and the pervasiveness of marine debris from the shallows of urban sources to the farthest and deepest parts of the ocean, there is cause for optimism.

Encouragingly, we are seeing a number of global initiatives and cross-sectoral working groups coming together to tackle the marine litter issue. Some of these include the group of experts on the scientific aspects of marine environmental protection (GESAMP: http://www.gesamp.org), the international whaling commission's scientific committee to assess the impacts of marine debris on cetaceans (IWC; https://iwc.int), the convention on biological diversity's expert workshop on practical guidance on preventing and mitigating the significant adverse impacts of marine debris on marine and coastal biodiversity and habitats (CBD; http://www.cbd.int/); and many others.

Coastal debris clean-ups continue to be positive educational and outreach experiences for people worldwide. Litter removal activities are restoring marine habitats and saving untold millions of marine organisms. Research continues to estimate the potential for impacts to diverse taxa as well as to identify taxa for monitoring the extent of problems and progress made. The finding that most plastic pollution is from local sources is positive, as it means that local solutions can be enacted that can substantially decrease the pollution load and its impacts. Furthermore, there is increasing public awareness and interest in tackling marine debris before it enters our waterways, as evidenced by the increasing public profile and the commitment of volunteers and citizen scientists around the world who spend their free time as custodians of their local coastal regions.

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