Tackling Marine Litter—LITTERBASE

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1 Background

Anthropogenic litter contamination of the oceans is a global problem of growing concern and currently receives strongly increasing attention by policy makers, public authorities, media and the general public. Unlike many other pollutants, marine litter on beaches and its deleterious effects on marine mammals, birds and turtles have attracted much attention as they can be directly observed by stakeholders. 'Blue environments' provide a sense of connectedness with nature to humans, which is, however, significantly compromised by the presence of anthropogenic litter (Wyles et al. 2015). This explains its importance in public perception, and it also shows that the issue lends itself well to showcasing both the importance of our oceans to humankind and at the same time the global extent of anthropogenic impacts on marine ecosystems.

Marine litter consists primarily of plastics, which does not come as a surprise given the durability of the material and that 8,300 million tons of plastics have been produced to date (Geyer et al. 2017). The recent discovery of the great oceanic garbage patches and of microplastic, a degradation product (≤ 5 mm) of larger items, has spurred new interest in this field of research, which is currently taking a

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large leap forward. Great efforts are being made to assess the impacts of this form of pollution on marine biota. This has disclosed an unexpected complexity of a seemingly simple environmental problem (Kühn et al. 2015; Lusher 2015). The number of records on the abundance and distribution of litter in more and more aquatic ecosystems and all oceanic regions is growing rapidly in the scientific literature, highlighting its ubiquity (Galgani et al. 2015). Between the late 1960s and 2016, scientific research on marine litter has yielded some 250 publications. But although this figure rose to 200 papers just between 2010 and 2013 (Ryan 2015), studies currently lack standardisation of methodology, which hampers comparison, qualification and quantification of the impacts on a global level (Galgani et al. 2015). The temporal and spatial coverage of studies mostly focuses on local areas or specific time periods, which does not improve our understanding of possible sources and transport mechanisms at a global scale. Accordingly, we currently only know where 1% of the total amount of plastic assumed to enter the oceans from land ends up (van Sebille et al. 2015). Considering the vastness of marine environments and the complex interactions between different ocean biomes, we urgently need baselines to extrapolate data and thus allow global assessments.

In a survey among 3,876 stakeholders, including representatives of industries, management, education, environmental organisations, and the general public from 16 European countries, most respondents were concerned about marine litter (87%) and conceived it as a severe threat to marine environments (80%) (Hartley et al. 2015). However, survey respondents beleived most litter to be near urban coastal areas and underestimated the proportion of marine litter items composed of plastic by 30%. In another, smaller, survey (n = 68), the majority of respondents' mistakenly believed that microplastics were primarily found on beaches and at the sea surface (S. Pahl cited in GESAMP (2015)). These examples highlight that, despite the topic's societal relevance, the rapidly growing scientific knowledge is currently poorly fed back to and used by society. Effective environmental policy and management, however, require sound scientific advice as well as effective processes that enable information uptake and feedback within and from societal stakeholders.

Here, we developed a tool with two main goals: (1) compile existing scientific knowledge to enable meta-analyses, which allow us to deduce global patterns of marine litter abundance, composition, distribution and ecological effects; (2) increase public understanding of marine litter by channelling scientific knowledge into accessible and understandable information products.

2 Scope and Motivation

Scientists from five different research groups at AWI currently focus on different facets of this environmental problem, i.e. on the impact of litter and microplastics on marine life, the distribution of litter and microplastics in different biomes and geographic regions and on methodological harmonisation. At a national level, the AWI is therefore currently conceived at the forefront of marine litter research such

that AWI scientists are frequently consulted by the media and public authorities for advice and information. For example, the institute's annual media resonance analysis showed that the press releases pertaining to this topic resulted in 686 citations in the press, reaching more than 37 million people in 2014 alone, a figure that does not even include enquiries independent of press releases. Queries of scholars or other interested parties refer primarily to basic but overarching issues such as current figures on global quantities, composition and distribution of marine litter, the number and kinds of biota affected, or the effects on marine life and human health. However, the rapid progress in marine litter research scattered all over the Globe has made information on this topic increasingly intangible and inaccessible to interested stakeholders who cannot extract the requested information. To overcome this, Bergmann et al. (2015) channelled the current state of research in the text book 'Marine Anthropogenic Litter' and then became aware that the compiled knowledge became outdated as the book was written because of the rapidly growing number of new research publications. To provide easily accessible, understandable and continuously updated statistics and information products on marine litter and microplastic, the online portal '*LITTERBASE*' was devised. Stakeholders using this portal include public authorities, policy makers, NGOs, media, scholars, education sector, fishing industry, the general public and plastic manufacturing industry. For the purpose of this text, a reference to litter hereafter refers to both microplastic and larger-sized items.

3 Materials and Methods

A scientific database was designed to allow standardisation and analysis of marine litter data. The need for the instant display of the latest data along with older entries and many-to-many relationships of study locations and findings precluded the use of simple data management and storage tools. Therefore, the database was implemented on PostgreSQL 9.5. The publications were grouped according to their focus on either litter distribution, or interaction between litter and biota, or on both. The position of each study location was stored separately so that as many details as possible could be displayed in the front-end maps. Information such as litter type, size, litter quantity unit, aquatic system, biome, interaction type and effect were defined as metadata categories and extracted. Taxonomic information of the species affected by litter was also included. Where possible, litter quantities were standardised during data entry. Interactive web-based data management forms were devised to facilitate a user-friendly entry of multidimensional information to LITTERBASE. The data management and front-end applications were implemented with open-source Java Exercise Evaluation Framework (JEEE) technologies (Spring framework, Hibernate, Tyhmeleaf) and deployed to Apache Tomcat 8.0.33 on the institute's server. Google chart API was used to produce graphs in the front-end to display the output of data analyses. Two geo-referenced maps (litter distribution and biota interaction) were implemented with ArcGIS 10.4.1 as part of

the front-end application. The AWI GIS Viewer 0.3.3 extension was used to publish ArcGIS projects as Web Map Services. Data were assembled as feature classes via database views to enable an instantaneous display of new entries and updates in maps. The most common metadata categories were used as selection criteria in the front-end application to allow stakeholders to filter and display scientific data in an understandable and user-friendly manner.

4 Results

LITTERBASE comprises two main components and its extensions:

(1) **Data entry** (**back end**). Most peer-reviewed publications on the distribution of aquatic litter and its impacts were selected from previous review articles and new content alerts of scientific journals. Information extracted from 1,593 publications providing records of the distribution and/or interactions from more than 7000 locations were entered into the scientific database (status February 2018). Bibliometric data of all publications were entered, as were metadata pertaining to litter type (e.g. plastic, glass, metal, fishing gear), litter size (i.e. nano, micro, macro), litter quantity unit (e.g. items km^{-2}, items km^{-1}, items m^3), aquatic system (e.g. marine, freshwater, estuary), biome (e.g. beach, sea surface, water column, benthic) and total litter quantity. Litter quantities were standardised to the same units to achieve comparability. However, the use of many different sampling and analysis methods in different studies precluded a categorisation of all litter densities into one uniform set of units. Therefore, all analysis methods and units were kept in the database for further scientific analysis, while only three unit systems (items km^{-1}, items km^{-2} and items m^{-3}), comprising 42% of all records, were provided as selection and display criteria in geo-referenced maps.

Data on biological interactions with litter were also extracted: location of field records, number of species affected, percentage of individuals affected, type of interaction incurred (e.g. entanglement, ingestion, coverage, rafting), effects on biota (e.g. injury, mortality, growth, behaviour), litter type, litter size, aquatic system and biome.

(2) **Online data portal LITTERBASE** (**frontend**). Stakeholders can view the data entered in continuously updated information products. The distribution of global litter quantities and of interactions between litter and marine life is, for example, displayed in interactive maps (Figs. 1 and 2). Using tick boxes, stakeholders can restrict the display to records from certain aquatic systems, biomes or litter sizes. Pie charts show the contribution of different materials to the litter records. Differences in the quantities of litter from different areas are reflected in the size of the mapped pie charts. Upon click on a pie chart, further information as well as bibliographic data pops up in a text box.

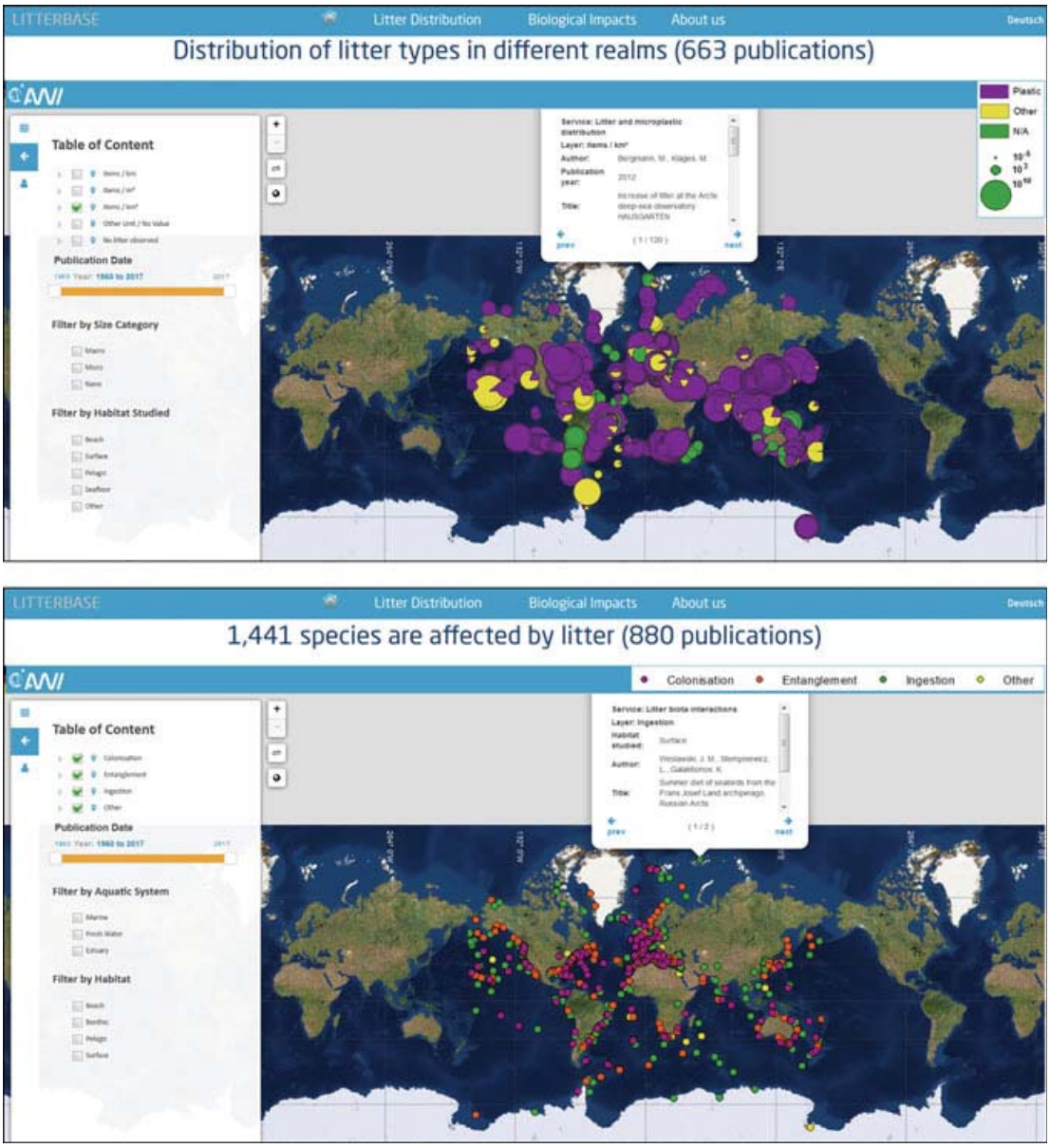

Fig. 1 Screenshots from LITTERBASE: (Top) Quantity and composition of litter and microplastic recorded from different locations worldwide. (Bottom) Field records of interactions between marine biota and litter from different locations worldwide (status 27/09/2017). Insert text box with information on record opens when clicking on points

In addition, information on the number and kinds of marine species affected by different types of litter can be viewed in pie charts. Data from laboratory experiments are also included in these information products but not shown in maps to preclude bias due to the position of laboratories.

Achievements of LITTERBASE during the first quarter after the launch

During the first year after the launch, the portal was visited about 77,284 times in 29,517 sessions Fig. 2. Maximum sessions per day were between 984 and 3,474 in the first month, probably as a result of a broadcast in the local TV news (Buten and

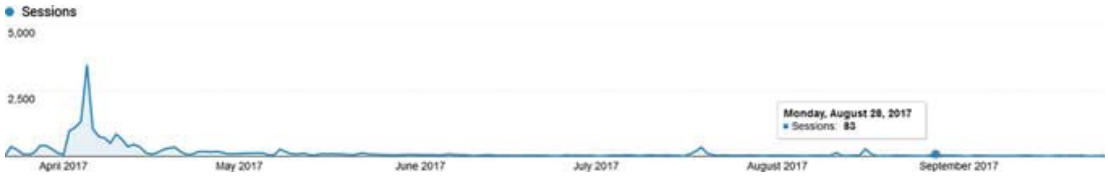

Fig. 2 Page visits per day (22/04-26/09/2017) from Google Analytics tool

Binnen). Mention of LITTERBASE in the News section of SCIENCE and in German newspapers instigated also increased page visits as did a communication about LITTERBASE in the high-ranking scientific journal NATURE (Bergmann et al. 2017).

Information from LITTERBASE was used in headlines of various Indian Newspapers and homepages stating "*Mumbai's sea-water most polluted globally*" or "*Vembanad Lake among most polluted in the world*". This is important as it highlights that the portal is being used by individual local stakeholders themselves to extract the information that they need. Additionally, both requests to use and offers to share further litter data were directed to the LITTERBASE team. These were put forward by scientists, regulators, scholars and teachers as well as citizens. LITTERBASE information graphics were also used in a geography text book for high school.

Currently, the homepage is visited on average by some 2,132 users per month. Twenty-one percent of the page visits are currently from German sites, followed by The Netherlands (14%), US (12%), France (9%) and others. Returning visitors account for 24%, new use for 76%. A Google Analytics survey returned 39,259 linkages (status February 2018), many of which were from German sites but also from US American, Asian, Russian, Italian, French, Dutch, Chilean and sites from other nations.

5 Reflection and Lessons Learned

The implementation of an online portal to aggregate and present scientific results goes beyond the usual activities of natural scientists and requires substantial support and close collaboration with contributors from other disciplines, primarily computing specialists. The development and implementation of LITTERBASE greatly benefited from the employment of an IT specialist with a strong environmental background and extensive experience in the topic of marine litter. Human resources with a broad expertise from multiple disciplines were essential for a successful implementation of the portal. However, such profiles clearly contrast the conventional development of specializations in academia. If online portals are to become an integral part of the knowledge transfer strategy of an institute, a prominent institutionalisation of this branch in the infrastructure and curriculum of the computing and other departments will be imperative to guarantee successful future developments and the sustainable long-term maintenance of the implemented technology.

6 Outlook

LITTERBASE is only one player in a concert of various online portals on marine litter, set up by other institutions. However, depending on the scientists and institutes involved, the various portals will have different *foci* and will hence provide different views on the same issue. A diverse supply of information from different sources will allow for a broad understanding of the marine litter problem in various stakeholder groups. Whether these diverse knowledge transfer activities actually contribute to the development of sustainable solutions to this eminent environmental problem is still difficult to assess and will have to be subject to dedicated social-science as well larger-scale interdisciplinary projects.

LITTERBASE will be subject to constant further development. Possible future extensions include geo-referenced litter observations made by citizens. Citizen science campaigns have the potential to substantially expand the spatial extent of investigations. The identification and quantification of anthropogenic litter in the environment and its multiple effects on the marine wildlife can easily be assessed by persons without specific scientific background, such as tourists, rangers, divers, fishers or members of the general public. Once added to the database, the results of citizen science campaigns can be viewed in combination with scientific data in the online portal thereby potentially enhancing connectedness of non-scientists with the specific research field.

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