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► **To cite this version:**

Martín Blettler, Karl M Wantzen. Threats Underestimated in Freshwater Plastic Pollution: Mini-Review. *Water, Air, and Soil Pollution*, 2019, 230 (7), 10.1007/s11270-019-4220-z . hal-02573273

HAL Id: hal-02573273

<https://hal.science/hal-02573273>

Submitted on 26 May 2020

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Water, Air, & Soil Pollution (2019) 230:174

<https://doi.org/10.1007/s11270-019-4220-z>

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Title

Threats underestimated in freshwater plastic pollution: mini-review.

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Key words

Plastic pollution, freshwater, macroplastic, entanglement, nesting material.

Abstract

Plastic pollution is one of the most acute environmental topics of our time. While there is a great scientific effort to tackle this problem, it has not always been well-coordinated or properly targeted. In this short review we call for scientists to get involved in three crucial topics (threats) underestimated -or ignored- in freshwater systems: i) plastic-species entanglement, ii) plastic as nesting material and iii) macroplastic debris coming from mismanaged household solid waste. Reducing the knowledge gaps between marine and freshwater environments will be crucial to solve the plastic pollution problem effectively and globally. Therefore, we make a plea here to reinforce research activities on these three issues in freshwater environments worldwide.

Introduction

Plastic has become an optimal material used in vast amounts of consumer products because it is lightweight, inexpensive, long lasting and a good insulator. Unfortunately,

within the last 35 years, scientists have realized that these useful attributes of plastics are what also make them detrimental to our environment (Sigler 2014). Rather than decomposing into molecular or further bio-gradable compounds plastic waste only photodegrades into smaller pieces that negatively affect marine and freshwater ecosystems. In the world's oceans, the economic damage of plastic waste has been estimated to 22 billion of Euro (Beaumont et al. 2019).

Compared with the increasing amount of research published in the ocean, the research of plastic-debris in freshwater environments is still undervalued. As a result, some critical topics, relatively well understood in marine environments, remain underestimated -or totally overlooked- in freshwater systems (Blettler et al. 2018). Concerns about the impact of plastics on freshwaters are legitimate and should receive more scientific attention (e.g. Lebreton et al. 2017).

With the objective to contribute to a more holistic vision on environmental effects of plastic pollution, this short review highlights least three crucial threats visibly underestimated in freshwater systems: i) plastic-species entanglement, ii) plastic-debris as nest-material, and iii) macroplastic debris as a result of the mismanagement of urban solid waste.

Material and methods

The literature review was based on the Scopus search engine (<https://www.scopus.com>). The Scopus search was defined as: TITLE-ABS-KEY “entanglement” OR “entangled” OR “nest material” OR “nesting material” AND “plastic pollution” OR “plastic debris” OR “plastic contamination”. Paper and reviews with no limits in years or subject area were considered (no book chapters). Note that this methodology was employed only for comparative reasons, i.e. to contrast marine with freshwater studies referred to “plastic-species entanglement” and “plastic-debris as nest-material” (objectives i and ii).

Therefore, our objective was not to record all the existing literature in the world, but rather a represented sample for comparative purposes. Therefore, we do not try to catch the total amount of existing papers on the selected topics (i.e. studies out-side the specific key-words are missing), but we obtained a representative sample. Subsequently, an exhaustive manual checking of the results (paper by paper) was performed at the discretion of the authors of this study, which was crucial to avoid papers outside the topic, repetitions, etc. Furthermore, a key review paper was used to extract processed information: Blettler et al. (2018) (see this paper for methodological details). Referring

to the size ranges, the plastic debris was termed macroplastic as >2.5 cm (NOAA, Lippiatt et al. 2013).

Results and Discussion

The reviewed papers in this study are 171 in total (62 from Scopus and 109 from Blettler et al., 2018). See “Supplementary data” section.

The Table 1 shows the scarcity of studies focused on plastic entanglement and nesting material in freshwater environments, and the clear dominance of microplastic over macroplastic studies in the same habitat.

Table 1. Percentage of peer-reviewing papers recorded on the topic of “plastic-species entanglement”, “plastic-debris as nest-material”, and “macroplastics” in freshwater ecosystems. Sources: Scopus for entanglement and nesting material (marine vs. freshwater; n= 62 articles reviewed); and Blettler et al. (June 2018) for macroplastic (macro vs. microplastic in freshwater; n= 109 articles reviewed).

		Marine environment	Freshwater
Topic of research	Entanglement (%)	98.3	1.6
	Nest-material (%)	16.6	0
		Freshwater microplastic	Freshwater macroplastic
	Macroplastics (%)	80	20

1. Plastic-species entanglement has not received attention in freshwater environments.

Entanglement happens when an animal becomes caught by a plastic object (rope, fishing line, abandoned net, bag, etc; NOAA 2014). Macroplastic debris entanglement reduce the ability to fly, swimming or run. Animals are also at risk of strangulation and suffocation by entanglement (Allen et al. 2012).

Over 690 different species of marine animals have been recorded as entangled in debris (Darmon et al. 2017), and more than 230 studies in total have been published on this topic (see LITTERBASE). However, plastic-species entanglement has been completely neglected by scientists in freshwater systems (Table 1). In spite of the quantification of entanglements of megafauna is difficult to assess for several reasons (detection and reporting biases or low detectability; Rodríguez et al. 2013), it has been successfully addressed in marine environments. Even if the scientific literature agrees that

entanglement is low detectable in the ocean (Votier et al. 2011), it seems to be frequent in the freshwater system nearby large cities. The Figure 1 shows some examples of aquatic species entangled in the Paraná (mega)River in Argentina, illustrating how common and dangerous entanglements can be in freshwater systems.

Figure 1. Examples of aquatic vertebrates entangled with plastic debris in the Paraná River (Argentina). a) *Pitangus sulphuratus* entangled in a piece of line fish; b) *Hoplias malabaricus* caught alive with a piece of fish line, entering through the mouth and leaving by the gills; c) *Pseudoplatystoma corruscans* trapped in an abandoned fish net (with lethal consequence). Photo credit: César Machado.

2. Use of plastic-debris as nest-material by freshwater birds.

Plastic particles may end up in bird nests either by chance (if they are similar to natural particles), or may be particularly selected for their shape or color by birds using ornamental elements in their nests to increase their conspicuousness in the context of female mate choice (Canal et al. 2016). The presence of plastic material in nests has been widely recorded in nests of several marine bird species (e.g. de Souza et al. 2016, Wang et al. 2018). The presence of plastic material in bird nests can reduce the survivability of both parent and chicks because they may consume or entangle themselves in the debris (Witteveen et al. 2017).

Although that phenomenon has been widely studied in marine birds, almost nothing is known about it in freshwater birds. However, personal field-observations confirmed a great presence of plastic debris in bird nests of many freshwater species (Figure 2). The record was done in the Negro (Brazil) and Paraná Rivers (Argentina), suggesting the necessity to address this issue in fluvial ecosystems. The amount of plastic trash ending up in the birds' nests appears to be increasing in freshwater systems, with dangerous and deadly results (Figure 2, c). As a direct effect, plastic particles in nests can reduce the survival rates of both parents and chicks because they may consume or entangle themselves in the debris (Witteveen et al. 2017), but little is known about the indirect impact of plastic nest material on the survival of fledglings due to changed physical (thermal resistance, water storage), hygienic (parasite development) and other unknown effects. We want to make a plea here to ornithologists to pay more attention to this growing but understudied ecological problem.

Figure 2. Presence of plastic-debris in nest of freshwater birds. a) Nest of *Phacellodomus sibilatrix* with several plastic debris in- and outside (Paraná River, Argentina). b) Cables, bottles caps, bag fragments, spoons, pens, cloth pegs, bobby pins and many other plastic debris found inside of one nest of *Pseudoseisura unirufa* (Negro River, Brazil). c) *Furnarius rufus* entangled in a piece of plastic used to build the nest (with lethal consequence; Paraná River, Argentina). Photo credits: Martín Blettler, Danilo Bandini Ribeiro and Pablo Cantador, respectively.

3. *Macroplastics from mismanagement of urban solid waste remain poorly studied in rivers.*

Recently, Blettler et al. (2018) revealed the clear dominance of microplastic studies over macroplastic ones in freshwater environments worldwide (Table 1). According to these authors, less than 20% of the total surveys in freshwater systems have been focused on macroplastics. These authors suggest several reasons to explain that crucial result: 1) microplastics have been identified as one of the top 10 emerging issues by the UNEP (2016), encouraging microplastic studies. 2) Microplastics are ingested by freshwater invertebrates and vertebrates (mainly fish; Triebkorn et al. 2019), which is of ecological and economic significance. 3) Smaller microplastics can be taken up by cells and translocate tissues (Khan et al. 2017). 4) Small plastic fragments may possibly have leaching rates of exogenous chemicals higher than those given by macroplastics, due to their proportionally greater surface (Wang et al. 2018). These four reasons could explain why microplastics have received more attention than macroplastics by scientists so far. However, we argue here that studies related to macroplastics, particularly from domestic solid waste mismanagement, in freshwater ecosystems should be fostered for five reasons: 1) recently, studies have estimated the amount of plastic (“solid load”) exported from rivers into the ocean (Lebreton et al. 2017, Schmidt et al. 2017). Given the scarcity of field-data in rivers, these authors developed models based on indirect proxies. This methodological strategy evidenced the lack of macroplastic field-data in rivers, preventing direct and accurate estimations. 2) Macroplastics represent a significantly greater input in terms of plastics weight compared with microplastics (>100 times according to Schmidt et al. 2017). 3) Urban solid waste management is one of the main key issues to be addressed both from developed and developing countries.

However, the domestic waste management in developing nations still remain strongly based on uncontrolled dumping (Guerrero et al. 2013). 4) Intercepting and removing macroplastics in rivers (e.g. using artisanal boom barriers or drainage nets) is an effective/low-cost action to avoid plastics reaching the ocean. On the contrary, the same action in the ocean is significantly more time consuming, expensive, and less effective due to the colossal scale of the ocean. Macroplastic removal from rivers using artisanal boom barriers or drainage nets can be cost-effective action compared to the marine plastic removal, which is significantly more time consuming, expensive, and less effective due to the colossal scale of the ocean. For example, The Ocean Cleanup project is a huge floating linear barrier deployed in the Great Pacific Garbage Patch. Beyond the scepticism of many researchers, the total cost of the system is the sum of 21 million euros (Forbes Media 2019). Finally, 5) macroplastic such as bags, bottles, food wrappers and fishing lines are the most common items in oceans which researchers have reported animals entangled in (Witteveen et al. 2017). All these macro-items are also present in freshwater environments (Morritt et al. 2014, Blettler et al. 2017), suggesting that many fluvial species can be likewise impacted by macro-debris and therefore at risk.

In the following, we suggest two possible causes for the fact that freshwater macroplastics have yet been understudied in freshwaters:

Differences in levels of development.

Research on freshwater plastic pollution have been mainly carried out in industrialized countries (Blettler et al. 2018). This is not surprising since the best nations in sciences are high-income economies (The Editors 2017). However, this disparity is particularly unsustainable from an environmental point of view, since: i) increasing population levels and the rise in consumption have greatly accelerated the solid waste generation rate in developing countries. However, waste collection and processing is still deficient in many low-middle income countries (UNHSP 2016). ii) Despite this, many developed countries (e.g. U.S, U.K) benefit from cost savings associated with exporting plastic waste to developing countries with less stringent environmental laws (e.g. Thailand, India, Malaysia; Liu et al. 2018), causing severe environmental problems. iii) The largest and populated river catchments in the world are located in developing countries (Latrubesse et al. 2008), with the potential highest input of pollution to the ocean (due to the poor sanitary conditions above described).

As a result, riverine macroplastic debris are not so evident in developed countries due to their management of waste, which is not always the case in developing countries, where a simple walk on a riverside and the plastic waste spectacle is present. Probably, this led to scientists from developed nations to center their effort on freshwater microplastic rather than macroplastic.

A case of intellectual imperialism?

Scientific imperialism is evident when it is detected a tendency to push a scientific idea (or topic of research) beyond the domain in which it was originally introduced (Alatas 2000). Many times, journal editors and researchers reproduce this dominance in order to attract new readers and publish more articles. This is particularly true in the case of microplastics, which became a hot-topic of study in the last years (Bergmann et al. 2017).

Accordingly, the authors suggest that microplastic pollution -as a topic of research- has been directly “imported” from developed countries to developing ones without scientific concerns or a critical view; i.e. without an agreement about its real importance in the context of the extreme levels of macroplastic pollution frequently find in rivers of emerging nations.

Conclusions

- 1) The impact of both “macroplastic entanglement” and “macroplastic as nesting-material” on freshwater fauna (and particularly birds) should be studied more intensively and compared with the marine environment. This holistic approach will allow scientists to design better solutions to reduce the ecological impact of plastic pollution, involving both marine and freshwater ecosystems as the two sides of the same coin.
- 2) Scientists from developing countries concerned about freshwater plastic pollution should not try to reproduce the research that lead to the scientific enterprise of the developed nations. Rather, they need to re-think the topics of research appropriate to their local circumstances (considering economic, environmental and social aspects), in attempting to solve the problems of their home countries. We suggest that more emphasis should be put on macroplastics in freshwater systems -particularly in large, populated and highly polluted river basins of developing countries- whether accurate estimations of the river plastic emissions to the world’s oceans are intended.

3) In spite of lacking accurate figures, the pollution of rivers with plastic (and the environmental impact) is evident. The most appropriate solution would be -of course- to produce less plastic and to recycle it better, or at least to hinder it from reaching the aquatic ecosystems by establishing stronger environmental legislation. As long as this is under way, a systematic cleanup of river ecosystems is urgently needed. The accurate assessment of the problem, and technological development for plastic removal, however, are yet unsatisfying, and the transboundary position of many rivers hampers political consent to take action.

Acknowledgments

This research was financially supported by The Rufford Foundation (Grant number: 26610-2). This paper was developed under the auspices of the UNESCO Chair on River Culture / Fleuves et Patrimoine granted to K.M. Wantzen. We would like to thank the reviewers for their thoughtful comments and efforts towards improving our manuscript.

References

- Alatas, S. H. (2000). Intellectual Imperialism: Definition, Traits, and Problems. *Southeast Asian Journal of Social Science*, 28, 23-45.
- Allen, R., Jarvis, D., Sayer, S., Mills, C. (2012). Entanglement of grey seals *Halichoerus grypus* at a haul out site in Cornwall, UK. *Marine Pollution Bulletin*, 64, 2815-2819.
- Beaumont, N. J., Aanesen, M., Austen, M. C., Börger, T., Clark, J. R., Cole, M., Hooper, T., Lindeque, P. K., Pascoe, C. and Wyles, K. J. (2019). Global ecological, social and economic impacts of marine plastic. *Marine Pollution Bulletin*, 142, 189-195.
- Bergmann, M., Wirzberger, V., Krumpfen, T., Lorenz, C., Primpke, S., Tekman, Mine B. (2017): Microplastics in Arctic deep-sea sediments from the HAUSGARTEN observatory. PANGAEA, <https://doi.org/10.1594/PANGAEA.879739>
- Blettler, M., Abrial, E., Khan, F., Sivri, N., Espinola, L. (2018). Freshwater plastic pollution: Recognizing research biases and identifying knowledge gaps. *Water Research*, 143, 416-424.
- Blettler, M., Ulla, M. A., Rabuffetti, A. P., Garelo, N. (2017). Plastic pollution in freshwater ecosystems: macro-, meso-, and microplastic debris in a floodplain lake. *Environmental Monitoring Assessment*, 189:581.

- Canal, D., Mulero-Pázmány, M., Negro, J. J., Sergio, F. (2016) Decoration Increases the Conspicuousness of Raptor Nests. PLoS ONE 11(7): e0157440.
- Darom, G., Miaud, C., Claro, F., Doremus, G., Galgani, F. (2017). Risk assessment reveals high exposure of sea turtles to marine debris in French Mediterranean and metropolitan Atlantic Waters. Deep-Sea Research Part II: Topical Studies in Oceanography, 141, 319-328
- de Souza Petersen, E., Krüger, L., Dezevieski, A., Petry, M., Montone, R. (2016). Incidence of plastic debris in sooty tern nests: A preliminary study on Trindade Island, a remote area of Brazil. Marine Pollution Bulletin, 105, 373-376.
- Forbes Media, (2019) LLC. <https://www.forbes.com/sites/jeffkart/2018/08/28/the-ocean-cleanup-is-starting-aims-to-cut-garbage-patch-by-90-by-2040/>
- Guerrero, L. A., Maas, G., Hogland, W. (2013). Solid waste management challenges for cities in developing countries. Waste Management. 33, 220-232.
- Khan, F. R., Boyle, D., Chang, E., Bury, N. (2017). Do polyethylene microplastic beads alter the intestinal uptake of Ag in rainbow trout (*Oncorhynchus mykiss*)? Analysis of the MP vector effect using in vitro gut sacs. Environmental Pollution. 231, 200-206.
- Latrubesse, E. M. (2008). Patterns of anabranching channels: The ultimate end-member adjustment of mega rivers. Geomorphology, 101, 130-145.
- Lebreton, L., van der Zwet, J., Damsteeg, J-W., Slat, B., Andrady, A., Reisser, J. (2017). River plastic emissions to the world's oceans. Nature Communication, 7:15611.
- Liu, Z., Adams, M., Walker, T. (2018). Are exports of recyclables from developed to developing countries waste pollution transfer or part of the global circular economy? Resources, Conservation & Recycling, 136, 22-23.
- Lippiatt, S., Opfer, S., Arthur, C. (2013). Marine debris monitoring and assessment. NOAA Technical Memorandum NOS-OR&R-46.
- LITTERBASE, Online Portal for Marine Litter <https://litterbase.awi.de/>
- Morritt, D., Stefanoudis, P. V., Pearce, D., Crimmen, O. A., Clark, P. F. (2014). Plastic in the Thames: a river runs through it. Marine Pollution Bulletin, 78, 196-200.
- NOAA, (2014). National Oceanic and Atmospheric Administration Marine Debris Program: Report on the Entanglement of Marine Species in Marine Debris with an Emphasis on Species in the United States. Silver Spring, 28.

- Rodríguez, B., Bécares, J., Rodríguez, A., Arcos, J. M. (2013). Incidence of entanglements with marine debris by northern gannets (*Morus bassanus*) in the non-breeding grounds. *Marine Pollution Bulletin*, 75, 259-63.
- Sigler, M. (2014). The effects of plastic pollution on aquatic wildlife: current situations and future solutions. *Water Air & Soil Pollution*, 225:2184.
- Schmidt, C., Krauth, T., Wagner, S. (2017). Export of plastic debris by rivers into the sea. *Environmental Science & Technology*, 51, 12246-12253.
- The Editors: *The World's Best Countries in Science*, (2017). Digital Science.
<https://www.scientificamerican.com/article/the-worlds-best-countries-science/>
- Triebkorn, R., Braunbeck, T., Grummt, T., Hanslik, L., Huppertsberg, S., Jekel, M., Knepper, T., Kraus, S., Müller, Y., Pittroff, M., Ruhl, A., Schmieg, H., Schür, C., Stobel, C., Wagner, M., Zumbülte, N., Köhler, H. (2019). Relevance of nano- and microplastics for freshwater ecosystems: a critical review *TrAC Trends Anal Chemistry*, 110, 375-379.
- United Nations Environment Programme, (2016). *Marine Plastic Debris and Microplastics. Global Lessons and Research to Inspire Action and Guide Policy Change*. UNEP, pp 274.
- United Nations Human Settlements Programme: *Urbanization and Development: Emerging Futures*, 2016. Nairobi, Kenya, pp 247.
- Votier, S. C., Archibald, K., Morgan, G., Morgan, L. 2011. The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. *Marine Pollution Bulletin*, 62, 168-172.
- Wang, F., Wong, C. S., Chen, D., Lu, X., Wang, F., Zeng, E. 2018. Interaction of toxic chemicals with microplastics: a critical review, *Water Research*, 139, 208-219.
- Witteveen, M., Brown, M., Ryan, P. 2017. Anthropogenic debris in the nests of kelp gulls in South Africa. *Marine Pollution Bulletin*, 114, 699-704.

Supplementary data

1) List of the articles recorded and reviewed on the topic of “plastic-species entanglement” and “plastic-debris as nest-material”. Sources: Scopus.

- Acampora, H., Lyashevskaya, O., Van Franeker, J. A., O'Connor, I. (2016). The use of beached bird surveys for marine plastic litter monitoring in Ireland. *Marine Environmental Research*, 120, 122-129.

- Avio, C. G., Gorbi, S., Regoli, F. (2017). Plastics and microplastics in the oceans: From emerging pollutants to emerged threat. *Marine Environmental Research*, 128, 2-11.
- Barreiros, J. P., Raykov, V. S. (2014). Lethal lesions and amputation caused by plastic debris and fishing gear on the loggerhead turtle *Caretta caretta* (Linnaeus, 1758). Three case reports from Terceira Island, Azores (NE Atlantic). *Marine Pollution Bulletin*, 86, 518-522.
- Baulch, S., Perry, C. (2014). Evaluating the impacts of marine debris on cetaceans. *Marine Pollution Bulletin*, 80, 210-221.
- Bearzi, G., Reeves, R. R., Remonato, E., Pierantonio, N., Airoidi, S. (2011). Risso's dolphin *Grampus griseus* in the Mediterranean Sea. *Mammalian Biology*, 76, 385-400.
- Beck, C. A., Barros, N. B. (1991). The impact of debris on the Florida manatee. *Marine Pollution Bulletin*, 22, 508-510.
- Bergmann, M., Tekman, M. B. and Gutow, L. (2017). LITTERBASE: An online portal for marine litter and microplastics and their implications for marine life. J. Baztan, B. Jorgensen, S. Pahl, R. Thompson and J. Vanderlinden (Editors). In: *Fate and impact of microplastics in marine ecosystems, MICRO 2016*, Amsterdam, Elsevier, 2 p. doi: 10.1016/B978-0-12-812271-6.00104-6
- Boren, L. J., Morrissey, M., Muller, C. G., Gemmell, N. J. (2006). Entanglement of New Zealand fur seals in man-made debris at Kaikoura, New Zealand. *Marine Pollution Bulletin*, 52, 442-446.
- Butterworth, A. (2016). A review of the welfare impact on pinnipeds of plastic marine debris. *Frontiers in Marine Science* (AUG), 3:149.
- Chiba, S., Saito, H., Fletcher, R., Yogi, T., Kayo, M., Miyagi, S., Ogido, M., Fujikura, K. (2018). Human footprint in the abyss: 30 year records of deep-sea plastic debris. *Marine Policy*, 96, 204-212.
- Chin, L. W., Fung, T. H. (2019). Plastic in Marine Litter. *Issues in Environmental Science and Technology*, 47, 21-59.
- Clemente, C. C. C. Paresque, K., Santos, P. J. P. (2018) The effects of plastic bags presence on a macrobenthic community in a polluted estuary. *Marine Pollution Bulletin*, 135, 630-635.

- Cliff, G., Dudley, S. F. J., Ryan, P. G., Singleton, N. (2002). Large sharks and plastic debris in KwaZulu-Natal, South Africa. *Marine and Freshwater Research*, 53, 575-581.
- Colmenero, A. I., Barría, C., Broglio, E., García-Barcelona, S. (2017). Plastic debris straps on threatened blue shark *Prionace glauca*. *Marine Pollution Bulletin*, 115, 436-438.
- Consoli, P., Andaloro, F., Altobelli, C., Battaglia, P., Campagnuolo, S., Canese, S., Castriota, L., Cillari, T., Falautano, M., Pedà, C., Perzia, P., Sinopoli, M., Vivona, P., Scotti, G., Esposito, V., Galgani, F., Romeo, T. (2018). Marine litter in an EBSA (Ecologically or Biologically Significant Area) of the central Mediterranean Sea: Abundance, composition, impact on benthic species and basis for monitoring entanglement. *Environmental Pollution*, 236, 405-415.
- Darmon, G., Miaud, C., Claro, F., Doremus, G., Galgani, F. (2017). Risk assessment reveals high exposure of sea turtles to marine debris in French Mediterranean and metropolitan Atlantic waters. *Deep-Sea Research Part II: Topical Studies in Oceanography*, 141, 319-328.
- de Souza Petersen, E., Krüger, L., Dezeveski, A., Petry, M., Montone, R. C. (2016). Incidence of plastic debris in Sooty Tern nests: A preliminary study on Trindade Island, a remote area of Brazil. *Marine Pollution Bulletin*, 105, 373-376.
- Duncan, E. M., Botterell, Z. L. R., Broderick, A. C., Galloway, T. S., Lindeque, P. K., Nuno, A., Godley, B. J. (2017). A global review of marine turtle entanglement in anthropogenic debris: A baseline for further action. *Endangered Species Research*, 34, 431-448.
- Fossi, M. C., Panti, C., Baini, M., Lavers, J. L. (2018). A review of plastic-associated pressures: Cetaceans of the Mediterranean Sea and Eastern Australian Shearwaters as case studies. *Frontiers in Marine Science*, 5:173.
- Franco-Trecu, V., Drago, M., Katz, H., Machín, E., Marín, Y. (2017). With the noose around the neck: Marine debris entangling otariid species. *Environmental Pollution*, 220, 985-989
- Gall, S. C., Thompson, R. C. (2015). The impact of debris on marine life. *Marine Pollution Bulletin*, 92, 170-179.
- Grant, M. L., Lavers, J. L., Stuckenbrock, S., Sharp, P. B., Bond, A. L. (2018). The use of anthropogenic marine debris as a nesting material by brown boobies (*Sula leucogaster*). *Marine Pollution Bulletin*, 137, 96-103.

- Green, D. S., Boots, B., Blockley, D. J., Rocha, C., Thompson, R. (2015). Impacts of discarded plastic bags on marine assemblages and ecosystem functioning. *Environmental Science and Technology*, 49, 5380-5389.
- Gregory, M. R. (2009). Environmental implications of plastic debris in marine settings-entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364, 2013-2025.
- Gündoğdua, S., Yeşilyurta, I., Erbaş, C. (2019). Potential interaction between plastic litter and green turtle *Chelonia mydas* during nesting in an extremely polluted beach. *Marine Pollution Bulletin*, 140, 138-145.
- Hanni, K. D., Pyle, P. (2000). Entanglement of pinnipeds in synthetic materials at South-east Farallon Island, California, 1976-1998. *Marine Pollution Bulletin*, 40, 1076-1081.
- Hardesty, B. D., Good, T. P., Wilcox, C. (2015). Novel methods, new results and science-based solutions to tackle marine debris impacts on wildlife. *Ocean and Coastal Management*, 115, 4-9.
- Harrigan, K. E. (1992). Causes of mortality of little penguins *eudyptula minor* in Victoria. *Emu*, 91, 273-277.
- Hartwig, E., Clemens, T., Heckroth, M. (2007). Plastic debris as nesting material in a Kittiwake-*(Rissa tridactyla)*-colony at the Jammerbugt, Northwest Denmark. *Marine Pollution Bulletin*, 54, 595-597.
- Hofmeyr, G., De Maine, M., Bester, M., Kirkman, S., Pistorius, P., Makhado, A. (2002). Entanglement of pinnipeds at Marion Island, Southern Ocean: 1991-2001. *Australian Mammalogy*, 24, 141-146.
- Hong, S., Lee, J., Jang, Y. C., Kim, Y. J., Kim, H. J., Han, D., Hong, S. H., Kang, D., Shim, W. J. (2013). Impacts of marine debris on wild animals in the coastal area of Korea. *Marine Pollution Bulletin*, 66, 117-124.
- Ivar do Sul, J. A., Santos, I. R., Friedrich, A. C., Matthiensen, A., Fillmann, G. (2011). Plastic Pollution at a Sea Turtle Conservation Area in NE Brazil: Contrasting Developed and Undeveloped Beaches. *Estuaries and Coasts*, 34, 814-823.
- Jones, M. M. (1995) Fishing debris in the Australian marine environment. *Marine Pollution Bulletin*, 30, 25-33.

- Laist, D. W. (1987). Overview of the biological effects of lost and discarded plastic debris in the marine environment. *Marine Pollution Bulletin*, 18 (6 SUPPL. B), 319-326.
- Lavers, J. L., Hodgson, J. C., Clarke, R. H. (2013). Prevalence and composition of marine debris in Brown Booby (*Sula leucogaster*) nests at Ashmore Reef. *Marine Pollution Bulletin*, 77, 320-324.
- Lawson, T. J., Wilcox, C., Johns, K., Dann, P., Hardesty, B. D. (2015). Characteristics of marine debris that entangle Australian fur seals (*Arctocephalus pusillus doriferus*) in southern Australia. *Marine Pollution Bulletin*, 98, 354-357.
- Li, W. C., Tse, H. F., Fok, L. (2016). Plastic waste in the marine environment: A review of sources, occurrence and effects. *Science of the Total Environment*, 566-567, 333-349.
- Lusher, A. L., Hernandez-Milian, G., Berrow, S., Rogan, E., O'Connor, I. (2018). Incidence of marine debris in cetaceans stranded and bycaught in Ireland: Recent findings and a review of historical knowledge. *Environmental Pollution*, 232, 467-476.
- Martin, J. M., Jambeck, J. R., Ondich, B.L., Norton, T. M. (2019). Comparing quantity of marine debris to loggerhead sea turtle (*Caretta caretta*) nesting and non-nesting emergence activity on Jekyll Island, Georgia, USA. *Marine Pollution Bulletin*, 139, 1-5.
- McIntosh, R. R., Kirkwood, R., Sutherland, D. R., Dann, P. (2015). Drivers and annual estimates of marine wildlife entanglement rates: A long-term case study with Australian fur seals. *Marine Pollution Bulletin*, 101, 716-725.
- Mellish, S., Pearson, E. L., Sanders, B., Litchfield, C. A. (2016). Marine wildlife entanglement and the Seal the Loop initiative: a comparison of two free-choice learning approaches on visitor knowledge, attitudes and conservation behavior. *International Zoo Yearbook*, 50, 129-154.
- Nash, A. D. (1992). Impacts of marine debris on subsistence fishermen: An exploratory study. *Marine Pollution Bulletin*, 24, 150-156.
- Nelms, S. E., Duncan, E. M., Broderick, A. C., Galloway, T.S., Godfrey, M. H., Hamann, M., Lindeque, P. K., Godley, B. J. (2016). Plastic and marine turtles: A review and call for research. *ICES Journal of Marine Science*, 73, 165-181.

- Nunes, J. A., Sampaio, C. L., Barros, F., Leduc, A. O. (2018). Plastic debris collars: An underreported stressor in tropical reef fishes. *Marine Pollution Bulletin*, 129, 802-805.
- O'Hanlon, N. J., James, N. A., Masden, E. A., Bond, A. L. (2017). Seabirds and marine plastic debris in the northeastern Atlantic: A synthesis and recommendations for monitoring and research. *Environmental Pollution*, 231, 1291-1301.
- Page, B., McKenzie, J., McIntosh, R., Baylis, A., Morrissey, A., Calvert, N., Haase, T., Berris, M., Dowie, D., Shaughnessy, P. D., Goldsworthy, S.D. (2004). Entanglement of Australian sea lions and New Zealand fur seals in lost fishing gear and other marine debris before and after Government and industry attempts to reduce the problem. *Marine Pollution Bulletin*, 49, 33-42.
- Panti, C., Baini, M., Lusher, A., Hernandez-Milan, G., Bravo Rebolledo, E. L., Unger, B., Syberg, K., Simmonds, M. P., Fossi, M. C. (2019). Marine litter: One of the major threats for marine mammals. Outcomes from the European Cetacean Society workshop. *Environmental Pollution*, 247, 72-79.
- Pemberton, D., Brothers, N. P., Kirkwood, R. (1992). Entanglement of Australian fur seals in man-made debris in tasmanian waters. *Wildlife Research*, 19, 151-159.
- Provencher, J. F., Bond, A. L., Avery-Gomm, S., Borrelle, S. B., Bravo Rebolledo, E. L., Hammer, S., Kühn, S., Lavers, J. L., Mallory, M. L., Trevail, A., Van Franeker, J. A. (2017). Quantifying ingested debris in marine megafauna: A review and recommendations for standardization. *Analytical Methods*, 9, 1454-1469.
- Rodríguez, B., Bécares, J., Rodríguez, A., Arcos, J. M. (2013). Incidence of entanglements with marine debris by northern gannets (*Morus bassanus*) in the non-breeding grounds. *Marine Pollution Bulletin*, 75, 259-263.
- Sazima, I., Gadig, O. B. F., Namora, R. C., Motta, F. S. (2002). Plastic debris collars on juvenile carcharhinid sharks (*Rhizoprionodon lalandii*) in southwest Atlantic. *Marine Pollution Bulletin*, 44, 1149-1151.
- Schrey, E., Vauk, G. J. M. (1987). Records of entangled gannets (*Sula bassana*) at Helgoland, German Bight. *Marine Pollution Bulletin*, 18 (6 SUPPL. B), 350-352.
- Stewart, B. S., Yochem, P. K. (1987). Entanglement of pinnipeds in synthetic debris and fishing net and line fragments at San Nicolas and San Miguel Islands, California, 1978-1986. *Marine Pollution Bulletin*, 18 (6 SUPPL. B), 336-339.

- Tavares, D. C., Da Costa, L. L., Rangel, D. F., De Moura, J. F., Zalmon, I. R., Siciliano, S. (2016). Nests of the brown booby (*Sula leucogaster*) as a potential indicator of tropical ocean pollution by marine debris. *Ecological Indicators*, 70, 10-14.
- Thiel, M., Luna-Jorquera, G., Álvarez-Varas, R., Gallardo, C., Hinojosa, I. A., Luna, N., Miranda-Urbina, D., Morales, N., Ory, N., Pacheco, A. S., Portflitt-Toro, M., Zavalaga, C. (2018). Impacts of marine plastic pollution from continental coasts to subtropical gyres-fish, seabirds, and other vertebrates in the SE Pacific. *Frontiers in Marine Science*, 5:238.
- Triessnig, P., Roetzer, A., Stachowitsch, M. (2012). Beach condition and marine debris: New hurdles for sea turtle Hatchling Survival. *Chelonian Conservation and Biology*, 11, 68-77.
- Verlis, K. M., Campbell, M. L., Wilson, S. P. (2014). Marine debris is selected as nesting material by the brown booby (*Sula leucogaster*) within the Swain Reefs, Great Barrier Reef, Australia. *Marine Pollution Bulletin*, 87, 180-190.
- Votier, S. C., Archibald, K., Morgan, G., Morgan, L. (2011). The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. *Marine Pollution Bulletin*, 62, 168-172.
- Waluda, C. M., Staniland, I. J. (2013). Entanglement of Antarctic fur seals at Bird Island, South Georgia. *Marine Pollution Bulletin*, 74, 244-252.
- Wilcox, C., Mallos, N. J., Leonard, G. H., Rodriguez, A., Hardesty, B. D. (2016). Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife. *Marine Policy*, 65, 107-114.
- Williams, R., Ashe, E., O'Hara, P. D. (2011). Marine mammals and debris in coastal waters of British Columbia, Canada. *Marine Pollution Bulletin*, 62, 1303-1316.
- Witteveen, M., Brown, M., Ryan, P. G. (2017). Anthropogenic debris in the nests of kelp gulls in South Africa. *Marine Pollution Bulletin*, 114, 699-704.
- Woods, J. S., Rødder, G., Veronesi, F. (2019). An effect factor approach for quantifying the entanglement impact on marine species of macroplastic debris within life cycle impact assessment. *Ecological Indicators*, 99, 61-66.

2) *List of the articles reviewed on the topic of “macroplastics vs. microplastics in freshwater environments”. Sources: Blettler et al. (2018).*

- Acha, E. M., Mianzan, H. W., Iribarne, O., Gagliardini, D. A., Lasta, C., Daleo, P. (2003). The role of the Río de la Plata bottom salinity front in accumulating debris. *Marine Pollution Bulletin* 46, 197-202.
- Anschöber, R., Heinisch, W. (2015). On the trail of microplastics: the first results of the large Austrian study "Plastics in the Danube" for Upper Austria. Information about the press conference. http://www.land-oberoesterreich.gv.at/Mediendateien/LK/PK_LR_Anschober_12.3.2015_Internet.pdf.
- Arias-Villamizar, C. A., Vazquez-Morillas, A. (2018). Degradation of conventional and oxodegradable high density polyethylene in tropical aqueous and outdoor environments. *Revista Internacional de Contaminación Ambiental* 34, 137-147.
- Baldwin, A. K., Corsi, S. R., Mason, S. A. (2016). Plastic Debris in 29 Great Lakes Tributaries: Relations to Watershed Attributes and Hydrology. *Environmental Science and Technology* 50, 10377-10385.
- Ballent, A., Corcoran, P. L., Madden, O., Helm, P. A., Longstaffe, F. J. (2016). Sources and sinks of microplastics in Canadian Lake Ontario nearshore, tributary and beach sediments. *Marine Pollution Bulletin* 110, 383-395.
- Bartolotta, J. F., Hardy, S. D. (2018). Barriers and benefits to desired behaviors for single use plastic items in northeast Ohio's Lake Erie basin. *Marine Pollution Bulletin* 127, 576-585.
- Biginagwa, F. J., Mayoma, B. S., Shashoua, Y., Syberg, K., Khan, F. R. (2015). First evidence of microplastics in the African Great Lakes: Recovery from Lake Victoria Nile perch and Nile tilapia. *Journal of Great Lakes Research* 42, 146-149.
- Blettler, M. C. M., Ulla, M. A., Rabuffetti, A.P., Garello, N. (2017). Plastic pollution in freshwater ecosystems: macro-, meso-, and microplastic debris in a floodplain lake. *Environmental Monitoring and Assessment* 189(11), 581.
- Brandsma, S. H., Nijssen, P., van Velzen, M. J. M., Leslie, H. A. (2013). Microplastics in river suspended particulate matter and sewage treatment plants (report), IVM Institut for Environmental Studies, VU University Amsterdam, Amsterdam, pp 20.
- Brandsma, S. H., van Velzen, M. J. M., Leslie, H. A. (2015). Microplastics in North Sea marine sediment and Dutch river suspended particle matter (report), IVM Institut for Environmental Studies, VU University Amsterdam, Amsterdam, pp 20.

- Browne, M. A., Galloway, T., Thompson, R. (2010). Spatial Patterns of Plastic Debris along Estuarine Shorelines. *Environmental Science and Technology* 44, 3404-3409.
- Bruge, A., Barreau, C., Carlot, J., Collin, H., Moreno, C., Maison, P. (2018). Monitoring litter inputs from the Adour river (southwest France) to the marine environment. *Journal of Marine Science and Engineering* 6, 24.
- Cable, R. N., Beletsky, D., Beletsky, R., Wigginton, K., Locke, B. W., Duhaime, M. B. (2017). Distribution and Modeled Transport of Plastic Pollution in the Great Lakes, the World's Largest Freshwater Resource. *Frontiers in Environmental Science* 5, 45.
- Canniff, P. M., Hoang, T. C. (2018). Microplastic ingestion by *Daphnia magna* and its enhancement on algal growth. *Science of the Total Environment* 633, 500-507.
- Capozzi, F., Carotenuto, R., Giordano, S., Spagnuolo, V. (2018). Evidence on the effectiveness of mosses for biomonitoring of microplastics in fresh water environment. *Chemosphere* 205, 1-7.
- Carr, S.A., Liu, J., Tesoro, A.G. (2016). Transport and fate of microplastic particles in wastewater treatment plants. *Water research* 91, 174-182.
- Castañeda, R. A., Avlijas S., Simard M. A., Ricciardi. A. (2014). Microplastic pollution in St. Lawrence River sediments. *Canadian Journal of Fisheries and Aquatic Sciences* 71, 1767-71.
- Collard F., Gasperi J., Gilbert B., Eppe G., Azimi S., Rocher V., Tassin B. (2018). Anthropogenic particles in the stomach contents and liver of the freshwater fish *Squalius cephalus*. *Science of the Total Environment* 643, 1257-1264.
- Corcoran, P. L., Norris, T., Ceccanese, T., Walzak, M. J., Helm, P. A., Marvin, C. H. (2015). Hidden plastics of Lake Ontario, Canada and their potential preservation in the sediment record. *Environmental Pollution* 204, 17-25.
- Correa-Herrera, T., Barletta, M., Lima, A. R. A., Jiménez-Segura, L.F., Arango-Sánchez, L. B. (2017). Spatial distribution and seasonality of ichthyoplankton and anthropogenic debris in a river delta in the Caribbean Sea. *Journal of Fish Biology* 90, 1356-1387.
- Costa, M. F., Silva-Cavalcanti, J. S., Barbosa, C. C., Portugal, J. L., Barletta, M. (2011). Plastics buried in the inter-tidal plain of a tropical estuarine ecosystem. *Journal of Coastal Research, Special Issue* 64, 339-343.

- Dantas, D. V., Barletta, M., Da Costa, M. F. (2012). The seasonal and spatial patterns of ingestion of polyfilament nylon fragments by estuarine drums (*Sciaenidae*). *Environmental Science and Pollution Research* 19, 600-606.
- Di, M., Wang, J. (2018). Microplastics in surface waters and sediments of the Three Gorges Reservoir, China. *Science of The Total Environment* 616, 1620-1627.
- Dris, R., Imhof, H., Sanchez, W., Gasperi, J., Galgani, F., Tassin, B., Laforsch, C. (2015). Beyond the ocean: Contamination of freshwater ecosystems with (micro) plastic particles. *Environmental Chemistry*, CSIRO Publishing, 32 pp.
- Dris, R., Gasperi, J., Rocher, V., Saad, M., Renault, N., Tassin, B. (2015). Microplastic contamination in an urban area: a case study in Greater Paris. *Environmental Chemistry* 12, 592-599.
- Dris, R., Gasperi, J., Rocher, V., Tassin, B. (2018). Synthetic and non-synthetic anthropogenic fibers in a river under the impact of Paris Megacity: Sampling methodological aspects and flux estimations. *Science of the Total Environment*, 618, 157-164.
- Eckert, E. M., Di Cesare, A., Kettner, M. T., Arias-Andres, M., Fontaneto, D., Grossart, H.-P., Corno, G. (2018). Microplastics increase impact of treated wastewater on freshwater microbial community. *Environmental Pollution* 234, 495-502.
- Eriksen, M., Mason, S., Wilson, S., Box, C., Zellers, A., Edwards, W., Farley, H., Amato, S. (2013). Microplastic pollution in the surface waters of the Laurentian Great Lakes. *Marine Pollution Bulletin* 77, 177-182.
- Faure, F., Corbaz, M., Baecher, H., de Alencastro, L. (2012). Pollution due to plastics and microplastics in Lake Geneva and in the Mediterranean Sea. *Archives des Sciences*, 65, 157-164.
- Faure, F., Gagnaux, V., Baecher, H., Neuhaus, V., de Alencastro, L. (2013). Microplastiques sur les plages et la surface du Léman. Résultats préliminaires. *Bulletin de l'ARPEA* 49, 15-18.
- Faure, F., Demars, C., Wieser, O., Kunz, M., de Alencastro, L. F. (2015). Plastic pollution in Swiss surface waters: nature and concentrations, interaction with pollutants. *Environmental Chemistry*, 12, 582-591.
- Fischer, E. K., Paglialonga, L., Czech, E., Tamminga, M. (2016). Microplastic pollution in lakes and lake shoreline sediments – A case study on Lake Bolsena and Lake Chiusi (central Italy). *Environmental Pollution*, 213, 648-657.

- Fok, L., Cheung, P. K. (2015). Hong Kong at the Pearl River Estuary: A hotspot of microplastic pollution. *Marine Pollution Bulletin*, 99, 112-118.
- Free, C. M., Jensen, O. P., Mason, S. A., Eriksen, M., Williamson, N. J., Boldgiv, B. (2014). High-levels of microplastic pollution in a large, remote, mountain lake. *Marine Pollution Bulletin* 85, 156-163.
- Gallagher, A., Rees, A., Rowe, R., Stevens, J., Wright, P. (2016). Microplastics in the Solent estuarine complex, UK: An initial assessment. *Marine Pollution Bulletin*, 102, 243-249.
- Gasperi, J., Dris, R., Bonin, T., Rocher, V., Tassin, B. (2014). Assessment of floating plastic debris in surface water along the Seine River. *Environmental Pollution*, 195, 163-166.
- Gil-Delgado, J. A., Guijarro, D., Gosálvez, R. U., López-Iborra, G. M., Ponz, A., Velasco, A. (2017). Presence of plastic particles in waterbirds faeces collected in Spanish lakes. *Environmental Pollution*, 220, 732-736.
- Hendrickson, E., Minor, E.C., Schreiner, K. (2018). Microplastic abundance and composition in western Lake Superior as determined via microscopy, Pyro-GC/MS and FTIR. *Environmental Science and Technology*, 52, 1787-1796.
- Hoellein, T. J., McCormick, A., Kelly, J. J. (2014). Riverine microplastic: abundance and bacterial community colonization. In: Joint Aquatic Sciences Meeting. Portland, OR, USA.
- Hoffman, M. J., Hittinger, E. (2016). Inventory and transport of plastic debris in the Laurentian Great Lakes. *Marine Pollution Bulletin*, 115, 273-281.
- Hohenblum, P., Frischenschlager, H., Reisinger, H., Konecny, R., Uhl, M., Mühlegger, S., Habersack, H., Liedermann, M., Gmeiner, P., Weidenhiller, B., Fischer, N., Rindler, R. (2015). Plastik in der Donau - Untersuchung zum Vorkommen von Kunststoffen in der Donau in Österreich, Umweltbundesamt - BOKU Report 0547, ISBN 978-3-99004-358-5, 120 pp.
- Hohenblum, P., Liebmann, B., Liedermann, M. (2015). Plastic and microplastic in the environment. Technical Report 0551, ISBN 978-3-99004-363-9, 31 pp.
- Holland, E. R., Mallory, M. L., Shutler, D. (2016). Plastics and other anthropogenic debris in freshwater birds from Canada. *Science of the Total Environment*, 571, 251-258.
- Horton, A. A., Svendsen, C., Williams, R., Spurgeon, D., Lahive, E. (2016). Large microplastic particles in sediments of tributaries of the River Thames, UK –

- Abundance, sources and methods for effective quantification. *Marine Pollution Bulletin*, 114, 218-226.
- Horton, A. A., Jürgens, M. D., Lahive, E., van Bodegom, P. M., Vijver, M. G. (2018). The influence of exposure and physiology on microplastic ingestion by the freshwater fish *Rutilus rutilus* (roach) in the River Thames, UK. *Environmental Pollution*, 236, 188-194.
- Hurley, R., Woodward, J., Rothwell, J. J. (2018). Microplastic contamination of river beds significantly reduced by catchment-wide flooding. *Nature Geoscience*, 11, 251-257.
- Imhof, H. K., Ivleva, N. P., Schmid, J., Niessner, R., Laforsch, C. (2013). Contamination of beach sediments of a subalpine lake with microplastic particles. *Current Biology* 23, 867-868.
- Imhof, H. K., Wiesheu, A. C., Anger, P. M., Niessner, R., Ivleva, M. P., Laforsch, C. (2018). Variation in plastic abundance at different lake beach zones - A case study. *Science of the Total Environment*, 613, 530-537.
- Imhof, H. K., Laforsch, C., Wiesheu, A. C., Schmid, J., Anger, P. M., Niessner, R., Ivleva, N. P. (2016). Pigments and plastic in limnetic ecosystems: A qualitative and quantitative study on microparticles of different size classes. *Water Research*, 98, 64-74.
- Ivar do Sul, J. A., Costa, M. F. (2013). Plastic pollution risks in an estuarine conservation unit. In: Conley, D. C., Masselink, G., Russell, P. E., O'Hare, T. J. (Eds.), *Proceedings 12th International Coastal Symposium (Plymouth, England)*, *Journal of Coastal Research*, Special Issue, 65, 48-53.
- Jabeen, K., Su, L., Li, J., Yang, D., Tong, C., Mu, J., Shi, H. (2017). Microplastics and mesoplastics in fish from coastal and fresh waters of China. *Environmental Pollution*, 221, 141-149.
- Khan, F., Syberg, K., Shashoua, Y., Bury, N. (2015). Influence of polyethylene microplastic beads on the uptake and localization of silver in zebrafish (*Danio rerio*). *Environmental Pollution*, 206, 73-79.
- Klein, S., Worch, E., Knepper, T. P. (2015). Occurrence and Spatial Distribution of Microplastics in River Shore Sediments of the Rhine-Main Area in Germany. *Environmental Science and Technology*, 49, 6070-6076.
- Laforsch, C. (2015). *Mikroplastik Analyse Nordrhein-Westfalen*, Universität Bayreuth, Technical Report, 35 pp.

- Lagarde, F., Olivier, O., Zanella, M., Daniel, P., Hiard, S., Caruso, A. (2016). Microplastic interactions with freshwater microalgae: Hetero-aggregation and changes in plastic density appear strongly dependent on polymer type. *Environmental Pollution*, 215, 331-339.
- Lahens, L., Strady, E., Kieu-Le, T.-C., Dris, R., Boukerma, K., Rinnert, E., Gasperi, J., Tassin, B. (2018). Macroplastic and microplastic contamination assessment of a tropical river (Saigon River, Vietnam) transversed by a developing megacity. *Environmental Pollution*, 236, 661-671.
- Lechner, A., Keckeis, H., Lumesberger-Loisl, F., Zens, B., Krusch, R., Tritthart, M., Glas, M., Schludermann, E. (2014). The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe's second largest river. *Environmental Pollution*, 188, 177-181.
- Lee, R. F., Sanders, D. P., (2015). The amount and accumulation rate of plastic debris on marshes and beaches on the Georgia coast. *Marine Pollution Bulletin*, 91, 113-119.
- Liedermann, M., Gmeiner, P., Pessenlehner, S., Haimann, M., Hohenblum, P., Habersack, H. (2018). A methodology for measuring microplastic transport in large or medium rivers. *Water*, 10:414.
- Lumesberger-Loisl, F., Gumpinger, C. (2015). Mikroplastik in Fischen: Pilotstudie in der oberösterreichischen Donau. Franz Lumesberger-Loisl & Clemens Gumpinger, Wels. Technical Report, 48 pp.
- Magni, S., Gagné, F., André, C., Della Torre, C., Auclair, J., Hanana, H., Parenti, C. C., Bonasoro, F., Binelli, A. (2018). Evaluation of uptake and chronic toxicity of virgin polystyrene microbeads in freshwater zebra mussel *Dreissena polymorpha* (Mollusca: Bivalvia). *Science of the Total Environment*, 631-632, 778-788.
- Mani, T., Hauk, A., Walter, U., Burkhardt-Holm, P. (2015). Microplastics profile along the Rhine River. *Scientific Reports* 5, 17988.
- Mason, S. A., Kammin, L., Eriksen, M., Aleid, G., Wilson, S., Box, C., Williamson, N., Riley, A. 2016. Pelagic plastic pollution within the surface waters of Lake Michigan, USA. *Journal of Great Lakes Research*, 42, 753-759.
- McCormick, A., Hoellein, T. J., Mason, S. A., Schlupe, J., Kelly, J. J. (2014). Microplastic is an abundant and distinct microbial habitat in an urban river. *Environmental Science and Technology*, 48, 11863-11871.

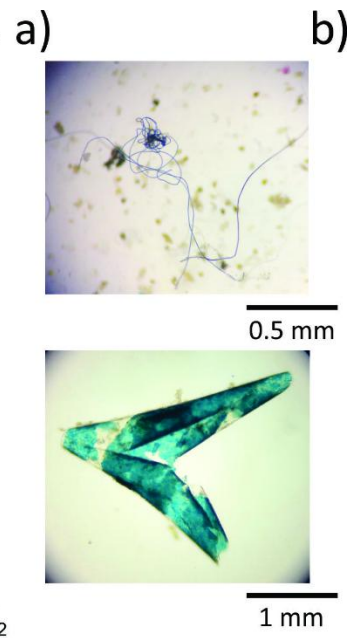
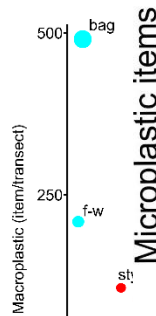
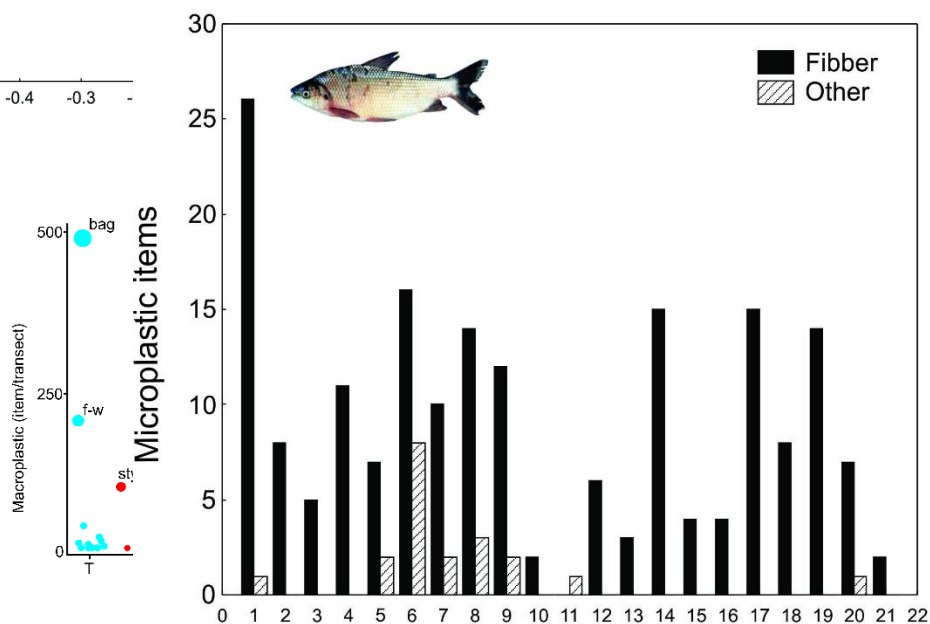
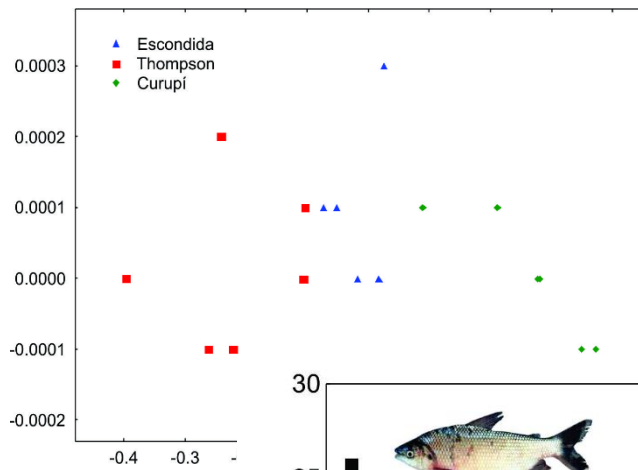
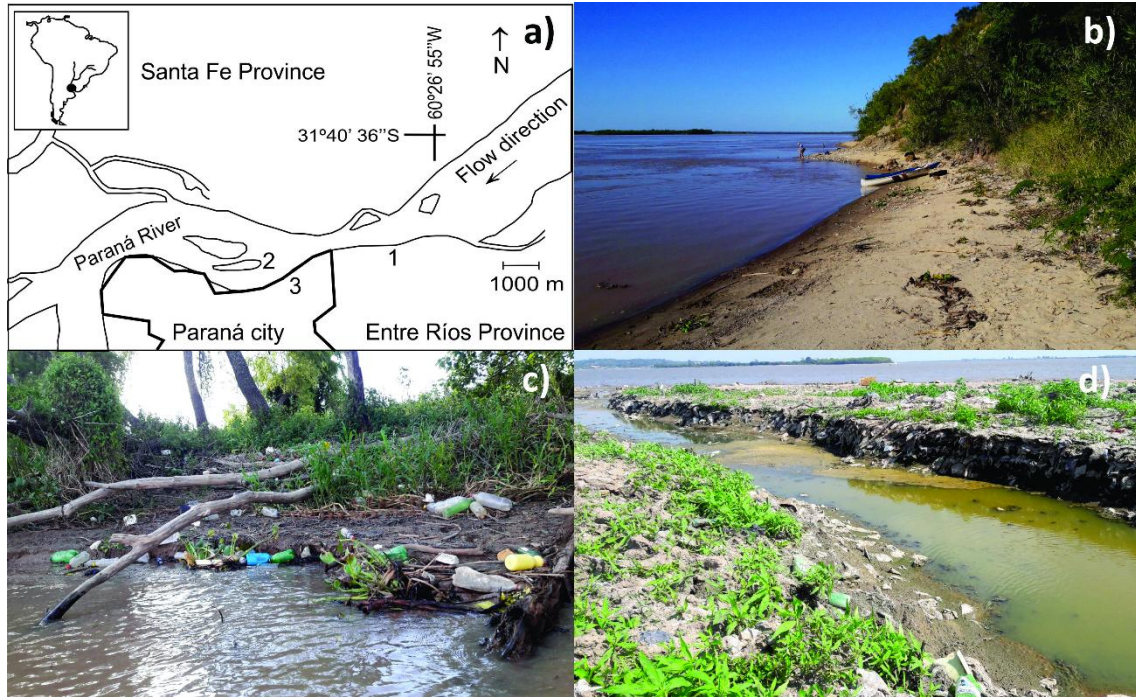
- McGoran, A. R., Clark, P. F., Morrith, D. (2017). Presence of microplastic in the digestive tracts of European flounder, *Platichthys flesus*, and European smelt, *Osmerus eperlanus*, from the River Thames. *Environmental Pollution*, 220, 744-751.
- Moore, C., Lattin, G., Zellers, A. (2011). Quantity and type of plastic debris flowing from two urban rivers to coastal waters and beaches of Southern California. *Journal of Integrated Coastal Zone Management*, 11, 65-73.
- Morrith, D., Stefanoudis, P.V., Pearce, D., Crimmen, O.A., Clark, P.F. (2014). Plastic in the Thames: A river runs through it. *Marine Pollution Bulletin*, 78, 196-200.
- Murphy, F., Ewins, C., Carbonnier, F., Quinn Wastewater, B. (2016). Treatment works (WwTW) as a source of microplastics in the aquatic environment. *Environmental Science and Technology*, 50, 5800-5808.
- Murphy, F., Quinn, M. (2018). The effects of microplastic on freshwater *Hydra attenuata* feeding, morphology and reproduction. *Environmental Pollution*, 234, 487-494.
- Naidoo, T., Glassom, D., Smit, A. J. (2015). Plastic pollution in five urban estuaries of KwaZulu-Natal, South Africa. *Marine Pollution Bulletin*, 101, 473-480.
- Nel, H. A., Dalu, T., Wasserman, R. J. (2018). Sinks and sources: Assessing microplastic abundance in river sediment and deposit feeders in an Austral temperate urban river system. *Science of the Total Environment*, 612, 950-956.
- Ogonowski, M, Schür, C, Jarsén, Å, Gorokhova, E. (2016). The Effects of Natural and Anthropogenic Microparticles on Individual Fitness in *Daphnia magna*. *PLoS ONE* 11(5): e0155063.
- Pate, J. A., McKinnon, E. E. (2016). A citizen engagement approach to water advocacy: Experiences from “eXXpedition Great Lakes”. *Maritime Affairs* 12, 99-108.
- Pazos, R., Maiztegui, T., Colautti, D., Paracampo, A., Gómez, N. (2017). Microplastics in gut contents of coastal freshwater fish from Río de la Plata estuary. *Marine Pollution Bulletin*, doi.org/10.1016/j.marpolbul.2017.06.007.
- Peng, G., Zhu, B., Yang, D., Su, L., Shi, H., Li, D. (2017). Microplastics in sediments of the Changjiang Estuary, China. *Environmental Pollution*, 225, 283-290.
- Peng, G., Xu, P., Zhu, B., Bai, M., Li, D. (2018). Microplastics in freshwater river sediments in Shanghai, China: A case study of risk assessment in mega-cities. *Environmental Pollution* 234, 448-456.

- Peters, C. A., Bratton, S. P. (2016). Urbanization is a major influence on microplastic ingestion by sunfish in the Brazos River Basin, Central Texas, USA. *Environmental Pollution*, 210, 380-387.
- Phillips, M. B., Bonner, T. H. (2015). Occurrence and amount of microplastic ingested by fishes in watersheds of the Gulf of Mexico. *Marine Pollution Bulletin*, 100, 264-269.
- Possatto, F. E., Barletta, M., Costa, M. F., Ivar do Sul, J. A., Dantas, D. V. (2011). Plastic debris ingestion by marine catfish: An unexpected fisheries impact. *Marine Pollution Bulletin*, 62, 1098-1102.
- Ramos, J. A. A., Barletta, M., Costa, M. F. (2012). Ingestion of nylon threads by Gerreidae while using a tropical estuary as foraging grounds. *Aquatic Biology*, 17, 29-34.
- Rech, S., Macaya-Caquilpán, V., Pantoja, J. F., Rivadeneira, M. M., Campodónico, C. K., Thiel, M. (2015). Sampling of riverine litter with citizen scientists –findings and recommendations. *Environmental Monitoring and Assessment*, 187:335.
- Rehse S., Kloas W., Zarfl C. (2016). Short-term exposure with high concentrations of pristine microplastic particles leads to immobilisation of *Daphnia magna*. *Chemosphere*, 153: 91-9.
- Reynolds, C., Ryan, P. G. (2018). Micro-plastic ingestion by waterbirds from contaminated wetlands in South Africa. *Marine Pollution Bulletin*, 126, 330-333.
- Rosenkranz, P., Chaudhry, Q., Stone, V., Fernandes, T. F. (2009). A comparison of nanoparticle and fine particle uptake by *Daphnia magna*. *Environmental Toxicology and Chemistry*, 28, 2142-2149.
- Sadri, S. S., Thompson, R. C. (2014). On the quantity and composition of floating plastic debris entering and leaving the Tamar Estuary, Southwest England. *Marine Pollution Bulletin*, 81, 55-60.
- Sanchez, W., Bender, C., Porcher, J-M. (2014). Wild gudgeons (*Gobio gobio*) from French rivers are contaminated by microplastics: preliminary study and first evidence. *Environmental Research* 128, 98-100.
- Scherer, C., Brennholt, N., Reifferscheid, G., Wagner, M. (2017). Feeding type and development drive the ingestion of microplastics by freshwater invertebrates. *Scientific Reports* 7: 17006.

- Sighicelli, M., Pietrelli, L., Lecce, F., Iannilli, V., Falconieri, M., Coscia, L., Di Vito, S., Nuglio, S., Zampetti, G. (2018). Microplastic pollution in the surface waters of Italian Subalpine Lakes. *Environmental Pollution*, 236, 645-651.
- Silva-Cavalcanti, J. S., Silva, J. S. B., Jose de França, E., Barbosa de Araújo, M. C., Gusmão, F. (2017). Microplastics ingestion by a common tropical freshwater fishing resource. *Environmental Pollution*, 221, 218-226.
- Sofra, C., Clarke, B., Fowler, G. (2010). *Microplastics in the Marine Environment: Investigating Possible Sources, Presence and Abundance*. Research Meeting, Dept of Civil and Environmental Engineering, Imperial College London, UK.
- Sruthy, S., Ramasamy, E. V. (2017). Microplastic pollution in Vembanad Lake, Kerala, India: The first report of microplastics in lake and estuarine sediments in India. *Environmental Pollution*, 222, 315-322.
- Su, L., Xue, Y., Li, L., Yang, D., Kolandhasamy, P., Li, D., Shi, H. (2016). Microplastics in Taihu Lake, China. *Environmental Pollution* 216, 711-719.
- Urgert, W. (2015). *Microplastics in the rivers Meuse and Rhine - Developing guidance for a possible future monitoring program*. Master's thesis Open University of the Netherlands, Heerlen, 106 pp.
- Wang, J., Peng, J., Tan, Z., Gao, Y., Zhan, Z., Chen, Q., Cai, L. (2016). Microplastics in the surface sediments from the Beijiang River littoral zone: Composition, abundance, surface textures and interaction with heavy metals. *Chemosphere*, 171, 248-258.
- Wang, L. S., Wu, Y. L., Liu, W. H., Li, M., Shi, J., Li, P., Zheng, J. (2016). Microplastic pollution of unspoiled beaches around Rongjiang River estuary. *Acta Scientiae Circumstantiae*, 36, 582-589.
- Wang, W., Yuan, W., Chen, Y., Wang, J. (2018). Microplastics in surface waters of Dongting Lake and Hong Lake, China. *Science of the Total Environment*, 633, 539-545.
- Warrack, S., Challis, J. K., Hanson, M. L., Rennie, M. D. (2017). Microplastics flowing into Lake Winnipeg: densities, sources, flux, and fish exposures. *Proceedings of Manitoba's Undergraduate Science and Engineering Research*, 3, 5-15.
- Weber, A., Scherer, C., Brennholt, N., Reifferscheid, G., Wagner, M. (2018). PET microplastics do not negatively affect the survival, development, metabolism and feeding activity of the freshwater invertebrate *Gammarus pulex*. *Environmental Pollution*, 234, 181-189.

- Williams, A. T., Simmons, S. L. (1996). The degradation of plastic litter in rivers: implications for beaches. *Journal of Coastal Conservation*, 2, 63-72.
- Xiong, X., Zhang, K., Chen, X., Shi, H., Luo, Z., Wu, C. (2018). Sources and distribution of microplastics in China's largest inland lake - Qinghai Lake. *Environmental Pollution*, 235, 899-906.
- Yonkos, L. T., Friedel, E. A., Perez-Reyes, A. C., Ghosal, S., Arthur, C. D. (2014). Microplastics in four estuarine rivers in the Chesapeake Bay, U.S.A. *Environmental Science and Technology*, 48, 14195-14202.
- Zbyszewski, M., Corcoran, P. L. (2011). Distribution and degradation of fresh water plastic particles along the beaches of Lake Huron, Canada. *Water, Air, and Soil Pollution*, 220, 365-372.
- Zbyszewski, M., Corcoran, P. L., Hockin, A. (2014). Comparison of the distribution and degradation of plastic debris along shorelines of the Great Lakes, North America. *Journal of Great Lakes Research*, 40, 288-299.
- Zhao, S., Zhu, L., Wang, T., Li, D. (2014). Suspended microplastics in the surface water of the Yangtze Estuary System, China: First observations on occurrence, distribution. *Marine Pollution Bulletin*, 86, 562-568.
- Zhao, S., Zhu, L., Li, D. (2015). Microplastic in three urban estuaries, China. *Environmental Pollution*, 206, 597-604.
- Zhang, K., Su, J., Xiong, X., Wu, X., Wu, C., Liu, J. (2016). Microplastic pollution of lake shore sediments from remote lakes in Tibet plateau, China. *Environmental Pollution*, 219, 450-455.
- Zhang, K., Xiong, X., Hu, H., Wu, C., Bi, Y., Wu, Y., Zhou, B., Lam, P., Liu, J. (2017). Occurrence and Characteristics of Microplastic Pollution in Xiangxi Bay of Three Gorges Reservoir, China. *Environmental Science and Technology*, 51, 3794-3801.
- Ziajahromi, S., Kumar, A., Neale, P., and Leusch, F. (2017). Impact of Microplastic Beads and Fibers on Waterflea (*Ceriodaphnia dubia*) Survival, Growth, and Reproduction: Implications of Single and Mixture Exposures. *Environmental Science and Technology*, 51, 13397-13406.
- Ziajahromi, S., Neale, P., Rintoul, L., Leusch, F. D. (2017). Wastewater treatment plants as a pathway for microplastics: Development of a new approach to sample wastewater-based microplastics. *Water Research*, 112: 93-99.

Figures and tables:



Type of debris	N° of items per transect (150 m ²) and Standard Deviation	%	Resin
Bag	166.2 ±252.1	48.75	HDPE, LDPE
Foodwrapper	68.3 ±110.1	20.05	PP, PS
Styrofoam	35.5 ±61.5	10.42	EPS
Beverage bottle	30.7 ±31.2	9.00	PET
Fishing line	8.5 ±15.7	2.49	Nylon



P. lineatus



Bottle cap

4.7 ±6.3

1.37

PP

Food containers (hard)	3.3 ±8.2	0.98	PS, PET
Cleaning bottle	3.2 ±4	0.93	HDPE, PET
Sanitary napkin	1.7 ±4.1	0.49	PP, PE
Household appliances	1 ±0.4	0.29	Undetermined
Personal care container	0.8 ±2	0.24	PP, HDPE, PET, PDPE, Varies
Strapping band	0.8 ±2	0.24	Polyester, PP
Cloth	0.3±0.5	0.10	Polyester
Bottle label	0.2 ±0.4	0.05	PET, PP, PVC
Straw	0.2 ±0.4	0.05	PP
Diaper	0.2 ±0.4	0.05	PP, PET
Cigarette butt	0.2 ±0.4	0.05	Cellulose acetate
Others	15.2 ±19.2	4.45	Undetermined
Total	340.8	100	
Site			
Escondida	52 ±42.4	5.1	
Curupí	190 ±77.1	18.6	
Thompson	780 ±14.1	76.3	

Table 2.

Mesoplastic Type	Escondida	Curupí	Thompson	Standard deviation	%
Styrofoam	47.8	35.5	16	48.3	89.3
Hard plastics	7.5	0	2.5	7.6	10
Fishing line	0.2	0	0	0.2	0.2
Cassette tape	0.2	0	0	0.2	0.2

Total (mean)	55.6	35.5	18.5	18.6	100
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Table 3.

	Escondida	Curupí	Thompson	Standard deviation	%	Category
Fiber	1431.4	90	4466.9	1899.6	33.1	Primary
Hard plastics	1424.2	18.8	421.7	51.8	0.9	Secondary
Styrofoam	33.2	11.3	36.2	2645.4	17.5	Secondary
Film	0	0.8	8953.5	6772.3	48.2	Secondary
Fiber-roll	0	0	72.9	54.5	0.4	Primary
Total (mean)	2899	131	12687	8548.1	100	

Table 4.

	r^2	p value
Macro- vs. meso-p	0.006	0.85
Meso- vs. micro-p	0.022	0.72
Micro- vs. macro-p	0.199	0.27