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Short communication

# The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe's second largest river

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ABSTRACT

Previous studies on plastic pollution of aquatic ecosystems focused on the world's oceans. Large rivers as major pathways for land-based plastic litter, has received less attention so far. Here we report on plastic quantities in the Austrian Danube. A two year survey (2010, 2012) using stationary driftnets detected mean plastic abundance ($n$ = 17,349; mean ± S.D: 316.8 ± 4664.6 items per 1000 $m^{-3}$) and mass (4.8 ± 24.2 g per 1000 $m^{-3}$) in the river to be higher than those of drifting larval fish ($n$ = 24,049; 275.3 ± 745.0 individuals. 1000 $m^{-3}$ and 3.2 ± 8.6 g 1000 $m^{-3}$). Industrial raw material (pellets, flakes and spherules) accounted for substantial parts (79.4%) of the plastic debris. The plastic input via the Danube into the Black Sea was estimated to 4.2 t per day.



## 1. Introduction

Plastic, the lightweight and long-lived material, has become a serious environmental hazard (Thompson et al., 2009). The annual global production of the organic polymer has rapidly increased from 1.7 to 280 million tonnes within the last 60 years (Plastics Europe, 2012) resulting in the accumulation of plastic litter in virtually all habitats (Browne et al., 2011). Marine systems are sinks for pre- and post-consumer plastic and the multifaceted negative impacts of plastic pollution on wildlife (reviewed in Cole et al., 2011; Derraik, 2002; Oehlmann et al., 2009) as well as several aspects of debris composition, distribution and abundance have been described here (reviewed in Ryan et al., 2009). Although accumulation of plastic in the ocean is prevalent, there is scarce data on plastic inputs in the oceans (Law et al., 2010). Marine plastics originate from ship or land-based sources (Coe and Rogers, 1997) with the latter to be of greater relevance (Andrady, 2011). A significant portion of the terrestrial plastic is transported to the seas by rivers. Nevertheless, quantifications of plastic loads in rivers found in primary literature are minimal (Moore et al., 2011). Realistic estimations of the plastic flow from rivers to oceans are very important in helping to raise the awareness of the sources of plastic debris and ultimately to drive measures to reduce it.

In this article, we present results from a two-year (2010, 2012) survey on plastic litter transport in Europe's second largest river, the Danube. The main aim of the study was to categorize and to quantify drifting plastic items. In a second step we compare plastic abundance and plastic mass in the river with those of ichthyoplankton (drifting fish larvae and juveniles). Adverse health effects may arise when small fish confuse plastic particles with food items (zooplankton, fish eggs) and ingest them (Carpenter et al., 1972). Finally we give a rough estimate of the input of plastic litter via the River Danube into the Black Sea. To our knowledge, this is the first report on plastic transport in a large river.

The whole study was embedded in a scientific project that highlights larval dispersal and the conservation of riverine fish populations. All sacrificed individuals were handled according to applicable regulations and used for comprehensive analysis (Lechner et al., 2013b).

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## 2. Methods

### 2.1. Study site

The study was conducted in a free flowing stretch of the Austrian Danube between Vienna and Bratislava. All sampling sites were situated within the "Danube Alluvial Zone National Park" which preserves the last remaining major wetlands environment in central Europe (http://www.donauauen.at). Here, the average river width is 350 m and the discharge at mean flow is 1930 $m^3 s^{-1}$. Featuring the world's most international river basin (19 countries, 800.000 $km^2$, 81 million people), the Danube is a special case study regarding conservation and management issues (Sommerwerk et al., 2009). As the main tributary (input of 6444 $m^3 s^{-1}$ at mean flow) and major nutrient pathway, the Danube directly affects the Black Sea (BSC, 2009). Beside eutrophication, the vulnerable ecosystems of this continental water face an increasing threat of plastic litter pollution (Topcu et al., 2013). Inputs from land-based sources have gained less attention but are supposed to be high, especially via the Danube River System (Lebreton et al., 2012).

### 2.2. Sampling

The sampling procedure has been accurately described elsewhere (Lechner et al., 2013b). Briefly, we utilized stationary conical driftnets (0.5 m diameter, 1.5 m long, 500 μm mesh) that were fixed to iron rods driven into the riverbed and sampled the top 0.5 m of the water column. Nets covered 60% of the water column in more than 75% of all cases. The mesh size we used is in the range of other studies that quantified suspended plastics (reviewed in Hidalgo-Ruz et al., 2013). A flowmeter (2030R, General Oceanics®, Miami) was attached to the lower third of each net entrance to measure the volume of filtered water. In this volume-reducing approach, the filtered sample (containing plastics, fish larvae, organic debris and other items) is collected in a jar attached to the net-end and can be taken to laboratory for further processing.

Duplicates (2010) and triplicates (2012) of driftnets were simultaneously exposed at three (2010) to four (2012) sampling stations along both river margins with maximum distances of 1 km between the single stations and 25 m between the shoreline and driftnets. In 2010, we sampled circadian (24 h) periods with hourly intervals between single sample events. In 2012, sampling started 2 h before sunset (according to ephemeris) and was continued in hourly intervals until midnight. Collecting day and night samples was essential in consideration of realistic comparisons between ichthyoplankton and plastics abundance: larval fish drift is known to exhibit a distinct diurnal rhythm with nocturnal peaks in individual numbers (Pavlov et al., 2008). Therefore, exclusive daytime sampling would have underestimated fish densities by far. The sampling period (Apr–Jul) was chosen to comprise the entire drift season (Lechner et al., 2013a). Before preservation in 96% alcohol, all fish were overdosed (500 mg/l) with the anesthetic tricaine methanesulfonate.

### 2.3. Sampling processing

In the laboratory, plastic items and fish larvae were separated from the samples in a two-step process. Each sample was suspended in a water bath and a density separation (buoyant plastic particles and larvae with intact swim bladders were removed), was followed by a careful visual sorting of the remaining material by the naked eye.

### 2.4. Characterization and quantification of plastics

All plastic pieces and larvae were counted. A subsample ($n = 500$) of fish larvae was taken and all individuals were weighed to the closest 0.01 g (moist mass). Each plastic particle was allocated to one of the categories shown in Fig. 1. *Pellets*, *spherules* and *flakes* characterize different types of industrial raw material that serve as precursors for plastics production. The category "*others*" encapsulates all other pieces and fragments of plastic consumer products. A subsample ($n = 500$) of each category was taken and all containing items were weighed to the closest 0.01 g and measured to the closest 0.01 mm (Zeiss® Axio Imager M1 with Axio Vision 4.8.2 software for image analysis). Referring to the size-ranges of the defined groups, the collected plastic may be termed mesodebris (2–20 mm; *pellets*, *flakes*, big *spherules*, *others*) or microdebris (<2 mm, small *spherules*) (Ryan et al., 2009) though different nomenclatures have been used in the literature (Cole et al., 2011; Hidalgo-Ruz et al., 2013). The abundance of fish larvae and plastics, below named drift density, is given as individuals and items per volume of filtered water (1000 $m^{-3}$). Additionally mass values of plastic and larvae are given in grams per volume (1000 $m^{-3}$). Means of larval and plastic drift densities were compared using Mann–Whitney *U*-tests (SPSS 20.0®, IBM Corp., Armonk, NY, USA). The plastic input (grams per 1000 $m^{-3}$) into the Black Sea (BS) was estimated using the simple formula,

$$\text{Input}_{BS} = \text{Load}_{NP} \times F_P$$

where the average plastic load (all categories combined) in the National Park ($\text{Load}_{NP}$) at mean flow (data derived from both sampling years) is multiplied by a factor reflecting the downstream increase in population in the Danube basin ($F_P$) (ICDPR, 2009; http://www.icpdr.org). Refining the result of this approximation by exploring the potential of applying an appropriately adapted sediment transport model coupled with hydrodynamic simulations (e.g. Tritthart et al., 2011) is envisaged for a future detailed study.

## 3. Results and discussion

In both years 951 drift samples were taken (day: 293, night: 658) containing a total of 24,049 young fish and 17,349 plastic items.

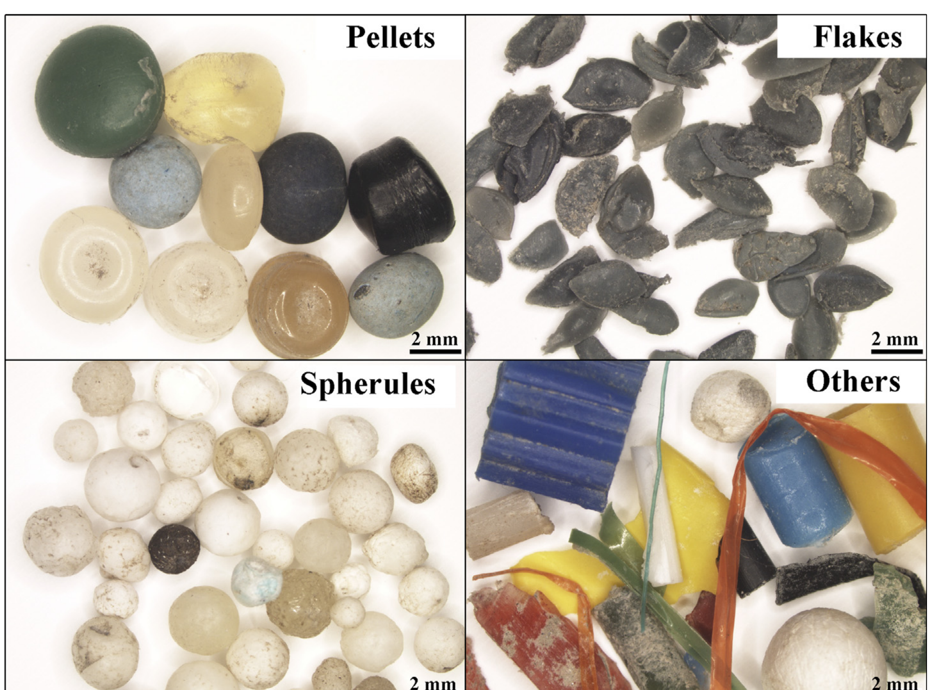


**Fig. 1.** Categories of drifting plastic items in the River Danube: pellets (mean weight ± S.D: 26.14 ± 4.5 mg; mean diameter ± S.D: 4.13 ± 0.48 mm), flakes (w: 2.23 ± 1.51 mg; d: 2.81 ± 0.51 mm), spherules (w: 4.45 ± 3.26 mg; d: 2.91 ± 0.65 mm), others (w: 51.6 ± 139.83 mg; d: 15.01 ± 12.58 mm).