Summary
of scientific
literature

EviEM Evidence Overview 2015

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Effects of nano- and microplastic particles on plankton and marine ecosystem functioning

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Effects of nano- and microplastic particles on plankton and marine ecosystem functioning

An Evidence Overview

Magnus Land

Abstract

Very small plastic particles are ubiquitous in the marine environment and have recently become a growing concern. Microplastics (often defined as < 5 mm) may affect marine biota in several ways: physically, by blocking or in other ways disturbing vital organs (e.g., feeding apparatus); chemically, by leaching toxic pollutants; or acting as hard substrates for rafting communities. Almost all of the field studies of microplastics in the marine environment found in this pilot study are dedicated to investigating the occurrence of microplastics rather than its effects on marine biota. However, several authors discuss potential effects and express an urgent need to study such effects. Recently, a limited number of laboratory studies investigating effects of small plastic particles on biota have been published. At present, a systematic review of this issue is not recommended due to the disparate nature and small amount of existing evidence.

Background

Plastic is one of the most used and versatile materials in the world. The global production in 2012 was 288 million metric tons (PlasticsEurope, 2013), and the distribution between the major polymers in 2007 was: polypropylene (PP), 24%; polyethylene (PE), 21%; and polyvinylchloride (PVC), 19% (Andrady, 2011). As a direct consequence of the extensive use of plastics in modern society, large amounts of plastic waste end up in the oceans. The sources of marine plastic pollution can be categorised into four major groups: tourism-related litter at the coast, sewage-related debris, fishing-related debris, and wastes from ships and boats (Allsopp et al., 2006). It is estimated that 20% of marine plastic debris comes from ocean-based sources, while around 80% derives from land-based sources (Allsopp et al., 2006). Jambeck et al. (2015) calculated that 4.8 to 12.7 million metric tons entered the ocean from 192 coastal countries in 2010 alone.

The size of plastic particles in the marine environment range from nano-scale fragments (<1 μm) to very large objects. Most plastics show high resistance to aging and minimal biological degradation. When exposed to UVB radiation in sunlight, the oxidative properties of the atmosphere and the hydrolytic properties of seawater, these polymers become brittle, and break into smaller and smaller pieces (Moore, 2008). This fragmentation may also be enhanced through wave action and sand grinding (Eriksson and Burton, 2003). Thus, even if the input of plastics to the oceans were to be terminated, which is unlikely within the foreseeable future, the amount of very small plastic particles in the marine environment could be expected to increase. There is little doubt that nanoscale particles are produced during weathering of plastics debris (Andrady, 2011). However, nanoparticles in air and water readily agglomerate into larger clusters or loose aggregates with other material. Nanoparticles incorporated in these aggregates can still be ingested by filter feeders (Ward and Kach, 2009) but it is not known if they will have the same physiological impact as the primary nanoparticles (Andrady, 2011).

Hidalgo-Ruz et al. (2012) classified the origin of microplastics (< 5 mm) in primary sources, including manufactured plastics of microscopic size (e.g., scrubbers in cosmetics and soaps or precursors for manufactured plastic products) and in secondary sources, such as plastics debris derived from the breakdown of larger plastic products. At present most microplastics in the marine environment originate from secondary rather than primary sources. While plastic pellets were very abundant between the 1970s and 1990s, their proportions seem to have decreased in recent years (Hidalgo-Ruz et al., 2012).

Today, plastics have been found in most marine habitats. Around 46% of plastics are buoyant and remain so until they are washed up on shore, or alternatively accumulate epifauna (Murray and Cowie, 2011) or increase in density due to weathering and bio-fouling (Hidalgo-Ruz et al., 2012), and sink. Vertical transportation of microplastics may be facilitated by wind-driven mixing (Kukulka et al., 2012) or through ingestion by organisms. In fact, microplastics are present in top sediment layers even at the deep-sea floor (Van Cauwenberghe et al., 2013). Some of these deep-sea sediments are situated at depths of 5000 m.

The abundance of microplastic particles in water samples taken using zooplankton nets (mesh openings 280–505 μm) from the coastal and open ocean in the Atlantic and Pacific have been reported in the range of 0-32.8 particles/m^3 (average ± SD; 1.9 ± 5.3 particles/m^3), which is similar to the range of 0.4-54.5 particles/m^3 sampled off the southern coast of Korea using a Manta trawl net (Song et al., 2014). In Swedish coastal waters, Norén (2007) captured up to 100 000 times greater concentrations of microplastics with an 80 µm mesh (150-2400 particles/m^3) than when using a 450 µm mesh (0.01-0.14 particles/m^3). A very high concentration, 102 000/m^3, of plastic particles (diam. ~0.5 – 2 mm) was found locally in the harbour outside a polyethylene production plant (Noren, 2007). In another recent Swedish study, the size fractions >10 µm and >300 µm were sampled, and even higher concentrations of microplastics were found in this size range (Norén et al., 2014).

The occurrence of microplastic debris is not restricted to water and sediment, but has also been detected in many marine organisms (Cole et al., 2013). Effects of plastic particles on marine organisms may be caused by the particles themselves as physical entities, or by chemicals released from the particles. The particles may be confused with food and lead to starvation or cause blockage of vital organs. Harmful chemicals can be part of the plastics (as additives), or they can be contaminants adsorbed to the plastic particles. Mato et al. (2000) found that plastic resin pellets play a role in transporting pollutants in marine environments. Studies have shown that plastics can adsorb and transport large quantities of PAH (Teuten et al., 2007) and PCB (Pascall et al., 2005), and that these compounds may be transferred to organisms (Teuten et al., 2009). Rochman et al. (2013) showed that plastic particles act as vectors transferring persistent, bioaccumulative and toxic substances (PBTs) from the water to food webs. In a review article, Engler (2012) concluded that while there is significant uncertainty and complexity in the kinetics and thermodynamics of the interactions, plastic debris may in this way cause adverse effects throughout the marine food web, which includes humans.

Because of the extremely long lifetime of plastic and PBTs in the ocean, prevention strategies are vital for minimising these risks. It should be noted, however, that all organic matter in the ocean may act as vectors for adsorbed organic contaminants, and that the amount transported by plastic particles is only a minute fraction of the total. Contaminants adsorbed by plastic particles would have been present in the oceans regardless of the presence of plastic particles: the plastic particles only contribute the additives. It may thus be argued that adsorbed contaminants are not a problem directly related to plastic particles, and to study effects of these in terms of chemical toxicity, it may be more relevant to focus on the effects of the additives.

The problem of plastic pollution has been recognised in the European Union's Marine Strategy Framework Directive (MSFD), which was adopted in 2008 (European Commission, 2008).

Identification of topic and stakeholders

The content of this document was originally produced as a feasibility study for a systematic review. As such it is important that the review question is relevant to stakeholders or users of the review.

At a general stakeholder meeting arranged by Mistra EviEM in 2012, a systematic review of the effects of plastic particles in seawater was suggested by the Swedish Agency for Marine and Water Management (SWAM). SWAM is responsible for the Swedish environmental quality objective "A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos". Other stakeholders concerned with this topic may include fisheries and conservation organisations and the plastics industry. Also, especially if knowledge gaps are identified, researchers and research councils may have an interest in an evidence overview of this topic.

Previously, Mistra EviEM published a pilot study where the proposed review question was "What are the effects of plastic particles on growth and mortality of marine organisms?" (http:/www.eviem.se/en/publications/pilot-studies/the-effects-of-plastic-particles-in-seawater/). In that pilot study, which was not focused on any particular size fraction of the plastic particles, it was concluded that a considerable amount of published reports exist that review this topic fairly exhaustive, but that most of the published studies report on the occurrence of plastic particles rather than the effects these particles have. The majority of field studies that reported on effects were designed in such a way that they are difficult to synthesize quantitatively (often they were case studies of individual specimens found to have suffered injuries or death from plastic particles). Quite frequently the studies reported on large animals such as dolphins, turtles, and sea birds, whose suffering can be particularly apparent.

In 2014, the Mistra EviEM secretariat was commissioned by the Mistra EviEM Executive Committee to more closely investigate the feasibility of conducting a systematic review of the effects of nanoparticles on smaller organisms, at the base of ecosystems, and on the ecosystems themselves.

Phrasing of review question

The word "nanoparticles" implies particle sizes of less than 1 µm. Such small particles are rarely described in the literature on plastic pollution. A much more common and generally accepted term is "microplastics", which at the International Research Workshop on the Occurrence, Effects, and Fate of Microplastic Marine Debris in 2008 tentatively was defined as fragments and primary-sourced plastics that are smaller than 5 mm (Arthur et al., 2009). Hidalgo-Ruz et al. (2012) noted that most studies reported two main size ranges of microplastics: (i) 1–500 µm and (ii) 500 µm–5 mm, and recommended that future programs of monitoring continue to distinguish these size fractions.

In Swedish coastal waters, Norén (2007) captured microplastics with mesh sizes of 80 µm and 450 µm. In another recent Swedish study two size fractions were sampled using a 10µm filter or a 300µm filter net (Norén et al., 2014). Cole et al. (2013) argued that sampling of microplastics in this size range is exceptional, and as such there is currently insufficient data to determine realistic environmental concentrations of these particles. The same authors concluded further that, due to the complexities of sampling and extraction and in the absence of unified sampling methodologies, microplastics are still considered to be an under-researched fraction of marine litter, with no consistent data relating to plastic detritus <333 µm in diameter. A study by Song et al. (2014) demonstrated that the quantity as well as the quality of microplastics are heavily dependent on both sampling method and type of water (bulk water vs. surface microlayer).

Given that significant sampling issues for very small particles are yet to be resolved, and that plankton is capable of ingesting particles larger than 1 µm (Wilson, 1973), the suggested review question probably needs to include micro-scale as well as nano-scale particles. The phrasing of the review question may thus be "What is the effect of nano- and microplastic particles on plankton and ecosystem functioning?"

The suggested review question contains the following PECO elements:

- Population/Subject: planktonic organisms (feeding by filtering, as scavenger and by particle engulfing, benthic filter feeders, benthic suspension feeders, benthic deposition feeders) and the ecosystems in which they live.
- Exposure: nano- and microscale plastic particles
- Comparator: no exposure
- Outcomes: changes in plankton communities and/or in ecosystem functioning

Methods

Searching for relevant literature and screening of identified articles have in some sense been systematic, although the searches have not been as comprehensive as usually is the case for EviEM systematic reviews. Only one literature database (Web of Science) has been used. No systematic search for grey literature has been carried out. However, bibliographies in review articles have been examined and searched for reports that were not captured by the searches in Web of Science. Furthermore, searches using the internet search engine Google have been performed. The table below shows used search strings in Web of Science and the number of hits they generated.

Table 1. Search strings used in Web of Science and corresponding search results (hits)[1].

Search	Search string	Hits
1	TOPIC: (nano* or micro*) and *plastic and (ecosystem or *plankton)	226
2	TOPIC: (nano* or micro*) and *plastic and ecosystem and *plankton	20
3	TOPIC: (nano* or micro*) and ecosystem and *plankton	3 763
4	TOPIC: (nano* or micro*) and ecosystem	28 641
5	TOPIC: (nano* or micro*) and *plastic and *particle and (plankton or ecosystem)	5
6	TOPIC: particles and plankton	1 184
7	TOPIC: particles and "ecosystem functioning"	58
8	TOPIC: particles and plankton and "ecosystem functioning"	4

[1] Searches were performed 2014-09-22, but articles published more recently have also been considered in this overview.

Scientific basis

A recent review by Ivar do Sul and Costa (2014) has summarized peer-reviewed literature on microplastics in the marine environment. The authors categorized the literature according to main focus of the articles (see Table 2). The most relevant foci for the review question in this evidence overview are “microplastics in plankton samples” and “ingestion of microplastics by invertebrates”. A closer look at these articles reveals that all articles in the first category (microplastics in plankton samples) are field studies. Marine pollution by synthetic fibres was first documented by Buchanan (1971). Carpenter and Smith (1972) documented pollution by plastic pellets and fragments. In one of the studies (Thompson et al., 2004) laboratory experiments were also carried out, where it was reported that microplastics were ingested by amphipods, lugworms, and barnacles. However, although potential effects of microplastics on plankton and ecosystems were discussed in most of the articles, none of the studies made any attempt to quantify or by any other means assess these effects. Collignon et al. (2012) argued that many aspects of the distribution of microplastics and their impact on the environment require further study, and that physiological effects related to plastic ingestion are poorly understood. Ingestion of plastic microparticles by filter feeders at the base of the food web is known to occur, but has not been quantified (Moore, 2008).

Table 2. Main focus of literature reviewed by Ivar do Sul and Costa (2014) displayed as number of articles in field- and laboratory-based studies. n=total number of articles in each category.

Main focus	n	Field	Lab	Effects quantified or assessed
Microplastics in plankton samples	25[1)]	22	1	0
Ingestion of microplastics by invertebrates	11	3	10	7
Ingestion of microplastics by vertebrates	26	[2)]	[2)]	[2)]
Microplastics in sediments	22	[2)]	[2)]	[2)]
Interactions of microplastics with pollutants	17	[2)]	[2)]	[2)]

[1)] Three of the papers do not involve any plankton samples. [2)] Not checked in this evidence overview.

In the second category of literature in the Ivar do Sul and Costa (2014) review (ingestion by invertebrates) most of the studies were laboratory-based, and in 7 of these various effects, or end points, were quantified or assessed. Three studies also reported on field surveys, but effects on the biota were not assessed. The main findings in the studies focusing on ingestion of microplastics by invertebrates are compiled in Table 3. Only one study (Cole et al., 2013) examined ingestion by plankton, where it was shown that 7.3 µm microplastics (>4000 mL^{-1}) significantly decreased algal feeding. According to the authors, findings imply that marine microplastic debris can negatively impact on zooplankton function and health.

The concentrations of nano- and microplastics used in most experiments are significantly higher than that observed in the marine environment. For example, in the study by Cole et al. (2013) concentrations of 4000-25000 polystyrene beads per ml were used, which, although the size fractions are slightly different, is 4-5 orders of magnitude greater than the highest concentration of synthetic

Table 3. Studies focusing on ingestion of microplastics by invertebrates.

Reference	Field	Lab	Effects quantified or assessed	Subject and main findings
Thompson et al. (2004)		X		Amphipods (detritivores), lugworms (deposit feeders), and barnacles (filter feeders). All organisms ingested microplastics.
Browne et al. (2008)		X	X	Mussel (*Mytilus edulis*). No short-term effects of 0.51 g/l of either 2 or 4-16 µm PS were observed.
Graham and Thompson (2009)		X		Sea cucumbers (*Thyonella gemmate, Holothuria floridana, Holothuria grisea, Cucumaria frondosa*). Ingestion of nylon and PVC fragments were greater than predicted based on plastic/sand grain ratios.
Murray and Cowie (2011)	X	X		*Nephrops.* 83% of the individuals sampled in the Clyde Sea contained plastics (predominately filaments) in their stomachs.
Braid et al. (2012)	X			Stranded Humboldt squid (*Dosidicus gigas*) on Chesterman Beach, Tofino, BC, Canada. Plastic pellets were present in six out of 17 stomachs on one occasion and in two out of 13 stomachs on another occasion.
Wegner et al. (2012)		X	X	Mussel (*Mytilus edulis*), PS nanoparticles (30 nm, 0.1-0.3 g/l), Production of pseudo feces and reduced filtering activity may in the long term lead to starvation.
von Moos et al. (2012)		X	X	Mussel (*Mytilus edulis*). <80 µm HDPE (2.5 g/l), significant increase in the end point granulocytoma formation and a significant decrease in lysosomal membrane stability (LMS). No effects were observed for the biomarkers of oxyradical damage (lipofuscin accumulation), disturbance in lipid metabolism (neutral lipid content) and in the condition index.
Besseling et al. (2013)		X	X	Lugworm (*Arenicola marina*), A positive relation was observed between microplastic concentration in the sediment and both uptake of plastic particles and weight loss by *A. marina*. A reduction in feeding activity was observed at a PS dose of 7.4% dry weight. A low PS dose of 0.074% increased bioaccumulation of PCBs by a factor of 1.1–3.6.
Cole et al. (2013)		X	X	Zooplankton (Copepoda, Tunicata, Euphausiacea, Chaetognatha, Cnidaria, Mollusca, Decapoda). 7.3 µm microplastics (>4000 mL−1) significantly decreased algal feeding. Findings imply that marine microplastic debris can negatively impact on zooplankton function and health.
Farrell and Nelson (2013)		X	X	Mussel (*Mytilus edulis*) and crab (*Carcinus maenas*), 0.5 µm PS spheres (approx. 10^9 particles/l), the amount of microplastic that transferred from *Mytilus edulis* to *Carcinus maenas* was small.
Ugolini et al. (2013)	X	X	X	Sandhopper (*Talitrus saltator*), 10-45 µm PE spheres (10% by weight in food), Preliminary investigations did not show any consequence of microsphere ingestion on the survival capacity in the laboratory. Sandhoppers can swallow microplastic together with food even in natural conditions.

polymers found in Swedish coastal waters (Norén et al. (2014). In a recent study not included in the review by Ivar do Sul and Costa (2014), Besseling et al. (2014) showed that plastic nanoparticles affect growth of *Scenedesmus obliquus* and reproduction of *Daphnia magna* using between 0.22 and 103 mg nano-polystyrene per litre. The authors acknowledged that such plastic concentrations are much higher than presently reported for marine waters as well as freshwater. Bhattacharya et al. (2010) studied the physical adsorption of nano-sized plastic beads (20 nm, 0.08-0.8 mg/ml) onto two living algal species, *Chlorella* and *Scenedesmus*, and showed that the adsorption of plastic beads hindered algal photosynthesis, possibly through the physical blockage of light by the nanoparticles and obstructed CO_2 and nutrient uptake pathways. It was also indicated that plastic adsorption promoted algal production of reactive oxygen species (ROSs are formed as natural by-products of normal metabolism, but levels may increase during environmental stress and cause damage to cell structure). Such algal responses to plastic exposure may have implications on the sustainability of the aquatic food chain. Wegner et al. (2012) studied the interaction between mussels (*Mytilus edulis*) and polystyrene nanoparticles (diam. 30 nm), and concluded that production of pseudo faeces (which expends energy) and reduced filtering activity may lead to starvation in the long term. These two studies (Bhattacharya et al. 2010; Wegner et al. 2012) were also laboratory experiments where the authors used significantly higher concentrations than can be expected to be found in the current marine environment.

A limited amount of additional information on the interaction of nanoparticles with biota is available, but apart from the studies already mentioned, most concerns non-organic, engineered nanoparticles such as oxides, metals, carbon nanotubes, and fullerenes. Although these have shown different levels of toxicity to algae (Hund-Rinke and Simon, 2006), zooplankton (Lovern and Klaper, 2006; Templeton et al., 2006), *Daphnia* sp. (Roberts et al., 2007), zebra fish embryos (Usenko et al., 2008; Zhu et al., 2007), bivalves (Gagne et al., 2008), fat-head minnows (Zhu et al., 2006), rainbow trout (Federici et al., 2007; Smith et al., 2007), and zebra fish (Asharani et al., 2008; Griffitt et al., 2008), the data cannot be reliably extrapolated to polymer nanoparticles (Andrady, 2011). Inorganic nanoparticles may carry some persistent organic pollutants (POPs) via surface sorption but plastic particles are expected to have much higher levels of both matrix-solubilised and adsorbed POPs.

Ingestion of microplastics has also been shown to occur in some earlier studies not included in the review by Ivar do Sul and Costa (2014) (e.g., by *Acartia tonsa* (Wilson, 1973), *Calanus pacificus* adults, copepodites and nauplii (Fernandez, 1979; Frost, 1977; Huntley et al., 1983), *Oxyrrhis marina* (Hammer et al., 1999), *Galeolaria caespito* larvae (Bolton and Havenhand, 1998), ciliates (Christaki et al., 1998; Juchelka and Snell, 1995), and by echinoderm larvae (Hart, 1991)). However, in most of these laboratory studies the main focus was on feeding behaviour and food selection mechanisms rather than on the fact that the particles were made of plastic and its possible effects.

In a laboratory study Chan and Witting (2012) investigated the impact of microplastics (90-106 µm) on salp feeding (salps are filter-feeding pelagic tunicates). They concluded that while microplastic ingestion is likely to occur in larger-sized salp subjected to a high microplastic concentration, clogging of feeding apparatuses is likely to occur in small-sized salp at medium to high microplastic concentrations. In both cases, the presence of pelagic microplastics is likely to have negative effects on survival, feeding efficiency, fecundity, and their role in the carbon cycle. More studies are needed to examine the biological and physiological consequences of microplastics ingestion by filter-feeders such as salp, as well as how these negative impacts may be magnified further up the food chain.

This evidence overview has also identified a small number of articles documenting transfer of microplastics between trophic levels in a food chain. In a field-based study, Eriksson and Burton (2003) suggested that microplastics were transferred from a pelagic fish species (*Electrona subaspera*) to fur seals (*Arctocephalus* spp.) on Macquarie Island, Australia. In a laboratory study, Farrell and Nelson (2013) showed that small amounts of microplastics were transferred from mussels (*Mytilus edulis*) to crabs (*Carcinus maenas*), and that microplastics can translocate to the haemolymph and tissues of the crab. Neither of these studies quantified any effects on the biota. However, effects have been documented in other studies. In a laboratory study by Mattsson et al. (2015), transfer of nanoparticles in the food chain algae (*Scenedesmus* sp.) – zooplankton (*Daphnia magna*) – fish (*Carassius carassius*) was investigated. The algae were exposed to 24 and 27 nm sulfonated polystyrene particles. The zooplankton were then allowed to feed on the algae, and finally the algae were fed to the fish. According to the study, fish feeding on plankton with plastic particles showed a different feeding behaviour compared to the control group. The nanoparticle-fed fish moved much more slowly and did not hunt as actively as did the control fish, resulting in feeding times almost twice as long for the nanoparticle-fed fish compared to the controls. The mean distance between the fish in each aquarium was smaller for the nanoparticle-fed fish than for the control fish. The nanoparticle-fed fish behaved more as a group during feeding and exhibited stronger shoaling behaviour than did the control fish. Another difference was observed in the swimming pattern during feeding. The control fish actively explored more of the aquaria when searching and hunting for food, whereas the nanoparticle-fed fish explored a smaller space. The study also showed metabolite changes in liver and muscle tissue among nanoparticle-fed fish, and that these fish exhibited morphological changes in brain and muscle tissue. Mattsson et al. (2015) argued that nanosized particles may have considerable effects on natural systems and ecosystem services derived from them. Changed behaviour and changed metabolism among fish, as a result of transfer of plastic nanoparticles in a food chain, was also demonstrated in a laboratory study by Cedervall et al. (2012). In this study 1-100 nm polystyrene particles were used. At least three independent metabolic parameters differed between control and test fish: the weight loss (possibly caused by an inhibited ability to utilize the energy reserves), the triglycerides:cholesterol ratio in blood serum, and the distribution of cholesterol between muscle and liver. This study also showed that the time it took the fish to consume 95% of the food presented to them was more than doubled for nanoparticle-exposed compared to control fish.

Aside from physical and chemical impacts, microplastics also have a potential role in providing a new hard-substrate habitat for rafting communities (Wright et al., 2013). Moore et al. (2001) found a monofilament line 10 cm below the sea surface to be colonised with diatoms and other microalgae. Recently, microplastics have been identified as an important oviposition resource for the pelagic insect *Halobates sericeus*, indicated by a positive correlation between *H. sericeus* eggs on microplastics and microplastic abundance (Goldstein et al., 2012). The authors concluded that population-level impacts of microplastics are largely unknown, but that changes in the population structure of *H. sericeus* may lead to ecosystem-wide consequences.

Conclusions

Virtually all of the field studies of microplastics in the marine environment found in this evidence overview investigate the occurrence of such pollutants rather than their effects on marine biota. However, several authors discuss potential effects and express an urgent need to study them more thoroughly than has been done do date.

A limited number of laboratory studies have investigated effects of nano- and microplastic particles on plankton and other organisms at the base of the food web. However, most studies have used concentrations of plastic particles significantly higher than that recorded in the marine environment. The environmental relevance of these studies is therefore difficult to assess. Furthermore, no study found in this evidence overview has examined the significance of different shapes of particles. Most effect studies have used smooth and/or spherical particles, but it is possible that sharp and angular particles may cause other or larger effects at lower and more likely concentrations. No study has examined effects at a population or ecosystem level. However, a few studies have shown that trophic transfer of microplastics may occur both in the field and in laboratory, and in some laboratory studies it has been shown that negative effects on individuals at the highest trophic level occur.

At present, a systematic review of the effects of microplastics on plankton and ecosystem functioning seems to be infeasible due to the small volume of evidence. Existing studies are relatively few, and the majority has investigated different species and different outcomes, making it difficult to synthesize the body of evidence quantitatively. However, it may be feasible to produce a systematic map showing organisms and outcomes (end-points) investigated.

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MISTRA EviEM
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EviEM Evidence Overview 2015

Microscopic plastic particles have been released into almost all marine environments. These particles can affect marine organisms in several different ways. Their effects on both single species and entire ecosystems have become a growing concern. This EviEM Evidence Overview summarises published research on the topic.

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An EviEM Evidence Overview provides a general picture of the state of knowledge for a certain environmental topic. It is based on a limited search for literature and thus does not claim to be comprehensive. One of the purposes of an Evidence Overview is to investigate whether the available evidence base is suitable for systematic review.

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