Plastics and the hidden majority – microplastics and the conservation implications for a threatened UK freshwater fish (Ref IAP2-18-62)

University of Stirling, Biological & Environmental Sciences
In partnership with Centre for Ecology & Hydrology (CEH)

Supervisory Team
Dr Colin Bull (Stirling)
Dr Elma Lahive (CEH)
Dr Richard Quilliam (Stirling), Prof Nigel Willby (Stirling) and Dr David Oliver (Stirling)

Overview

Accumulation and integration of microplastics (plastic pieces < 5mm, hereafter referred to as MPs) in freshwater environments are relatively less studied in comparison to marine systems. Recent studies have indicated that MPs are diverse in nature, widely distributed, and can have local hot-spots of accumulation. A recent study has indicated that densities of over 500,000 particles per m² are present in some sediments in urban rivers. It is becoming clear that MPs are not only distributed widely throughout riverine habitats, but are being ingested by many organisms, including some larval fish species. Concern is growing regarding the potential toxicity of leachates from the plastics themselves and chemicals that can become bound to the surfaces of MPs (e.g. fire retardants and antimicrobial agents), on organisms that directly or indirectly ingest them. Studies in North America have reported dangerously high levels of contaminants (e.g. pesticides, flame retardants and mercury) in tissues of some native lampreys.

The UK contains three native species of lamprey: the River lamprey (Lampetra fluviatilis), Brook lamprey (Lampetra planeri) and Sea lamprey (Petromyzon marinus). All three species have a protected status, with many examples of sites supporting lamprey populations being designated as Special Areas of Conservation (SACs). However, despite their ecological importance, we still have limited knowledge of their ecology and secretive life cycle.

Larval lampreys are primary consumers, and UK species spend an average of five years in freshwater environments filter-feeding in burrows made in fine sand and deposited river sediment. These are the same types of river habitat that MPs reach their highest recorded densities. High larval densities are often found in the vicinity of spawning sites with older, larger animals occupying habitats towards the lower reaches of rivers.

Temperate freshwater ecosystems rely heavily upon the activity of organisms that process organic detritus, releasing nutrients via their processing, or through them becoming prey for larger organisms. The action of burrowing by lamprey larvae enables bioturbation and facilitates nutrient processing. Returning adult lampreys can also redistribute considerable volumes of streambed substrates during the preparation of spawning pits. Accordingly, lampreys are considered to be important ecosystem engineers of freshwater systems.

Burrowing provides larval lampreys with a concentrated solution of food in the form of organic particles, algae and bacteria. Particles are pumped into
the mouth and particle selection is likely made based on size by the oral ciliae. Small particles subsequently get trapped by mucus in the pharynx prior to being passed to the midgut. Research suggests that organic detritus and sand particles make up the majority of gut contents in larvae, along with a much smaller proportion of algae and bacteria. Algae collected from larval lamprey guts range from 260-400 µm, whilst organic particles and sand grains in the gut can be as small as 30µm.

There does not appear to be a relationship between the sizes of the particles ingested and body length, suggesting that young or older larvae are equally vulnerable to ingestion of MPs in river sediments. The rate of larval lamprey feeding and growth is maximised during the Spring and Summer months. During these periods, flows are generally low and consistent in UK rivers, and the deposition and accumulation of small MP particles may elevate their potential for ingestion by larval lampreys. With submicron or even nanometre size MPs likely to be present in sediments occupied by larvae, their role in facilitating direct release or surface transfer of toxins, and subsequent impacts on threatened UK lampreys, requires investigation.

Key research questions:
1) What is the extent of MP ingestion by larval lampreys?
2) Do larval lampreys avoid MP particles in contaminated sediments?
3) What are the ecotoxicological and behavioural effects of MPs on larval lampreys?
4) What are the implications of MP ingestion for provision of aquatic ecosystem services by threatened lampreys in UK rivers.

Methodology

Field work will be focused on UK lamprey species and will address research questions 1 and 2, with selection of sampling sites finalised in conjunction with Scottish Natural Heritage (SNH). Field studies will focus on threatened lampreys in UK rivers.

Tank based research to address question 3 will be carried out at the University of Stirling, drawing on the extensive experience and facilities available in the Institute of Aquaculture. Larval lamprey will be collected from wild populations and transferred to tanks in the laboratory where careful control over the environmental conditions, exposure to MPs, and monitoring of aspects of behaviour can be achieved. Criticisms of controlled studies in the past have been directed at the use of artificially high concentrations of MPs used in exposures, with results lacking realism of environmental conditions. To address this, data collected from the field studies will inform the choice of MP and exposure levels that larvae will be exposed to during controlled laboratory trials. Choice chambers or selection experiments using gradients of MP concentration may be utilised to investigate larval avoidance behaviour. Subtle behavioural changes following exposure to MPs will be assessed by recorded video analysis. Survival and growth will be monitored over the course of all tank-based experiments.

The student will also benefit from co-supervision from Professor Colin Bean, who is a senior science and policy advisor with Scottish Natural Heritage.

Timeline

The three phases of the project will take 36 months to complete, with remaining time allocated to writing, conference presentations and researcher networking development.

**Phases**

**Phase 1:** During phase 1 (months 0-5) a critical review of the literature will be undertaken along with Home Office ASPA licence preparation and training. Development of the sampling strategy and methods and training by partner organisations will be conducted during his initial phase.

**Phase 2:** An intensive field monitoring programme will be conducted (months 6-12) allowing samples to be collected and preserved. Fieldwork will be followed by a period of laboratory-based analysis at CEH Wallingford (months 13-15) where the extent of MP larval interactions will be established and quantified.

**Phase 3:** Tank-based studies will be undertaken at the University of Stirling where the specifics of MP
ingestion and effect on larval behaviour will be established. Data will then be integrated from all the three project phases to produce targeted manuscripts for publication.

**Training & Skills**

This studentship project will provide extensive opportunities to develop expertise for a research career. Supervisory input from the interdisciplinary team will provide the student with a range of training opportunities to broaden their skills base. Specific training will be provided in field sampling of lamprey and river habitats, dissection, advanced microscopy and ecotoxicology, statistical analysis and experimental behavioural ecology methods including image analysis. Specific methodologies have been developed for MP characterisation at CEH Wallingford, and specialist equipment and training will be made available. By working in close partnership with SNH, the student will also gain an understanding of the current issues surrounding rare species and protected site management and regulatory agendas. A Home Office project licence and personal licence training will be required prior to phase 3 tank-based studies.

**References & Further Reading**


**Further Information**

Further information and informal enquiries contact: Dr Colin Bull c.d.bull@stir.ac.uk tel 01786 467869