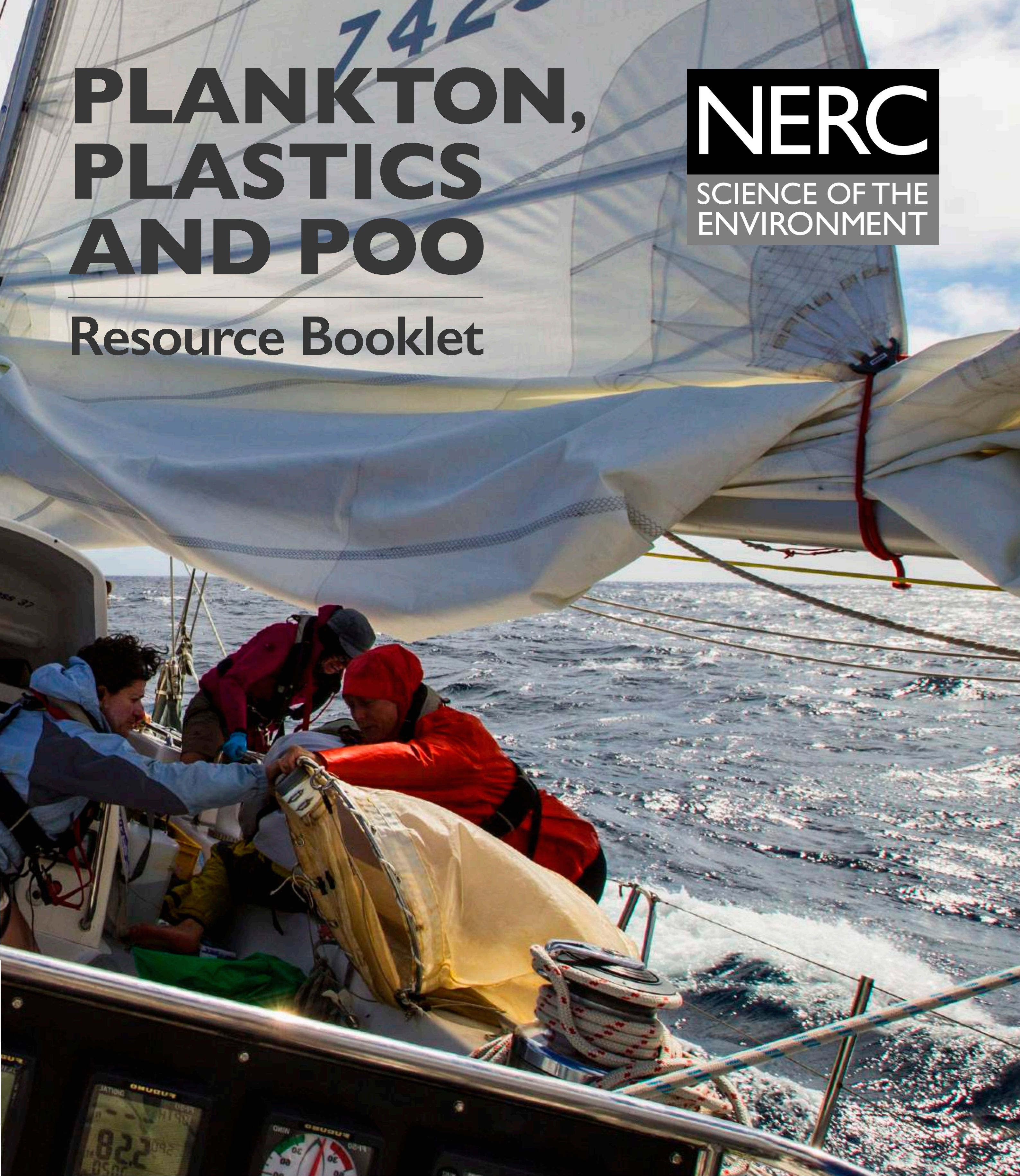
PLANKTON, PLASTICS AND POO

Resource Booklet

NERC
SCIENCE OF THE ENVIRONMENT



Become a field scientist

GCSE Biology / Combined Science working scientifically project

A resource by [digital explorer] with University of Exeter and PML Plymouth Marine Laboratory

About Digital Explorer

Digital Explorer is an award-winning education social enterprise based in London. A pioneer in the development of innovative real-world learning programmes, Digital Explorer supports teachers and students internationally to understand and engage with critical global issues from the oceans to cultural understanding.

About NERC

NERC - the Natural Environment Research Council - is the leading funder of independent research, training and innovation in environmental science in the UK.

We invest public money in world-leading science, designed to help us sustain and benefit from our natural resources, predict and respond to natural hazards and understand environmental change. We work closely with policymakers and industry to make sure our knowledge can support sustainable economic growth and wellbeing in the UK and around the world.

About the University of Exeter

Biosciences at the University of Exeter is a rapidly expanding international centre with researchers working at the cutting edge of Systems Biology and Systems Ecology research. They have an established reputation for working collaboratively with industry to deliver innovative solutions to real world problems.

About Plymouth Marine Laboratory

PML is an independent, impartial provider of scientific research in the marine environment, with a focus on understanding biodiversity and ecosystem function, which is critical to providing solutions in terms of measures of ecological sensitivity, biogeochemical cycling, pollution and health, scaling biodiversity and forecasting the role of the oceans in the Earth system.

About Sea Musketeers

Sea Musketeers thinks everyone should have the opportunity to learn about the ocean. We're working to create resources based on the latest expedition science and our own adventures at sea. With a strong focus on innovation and novel technologies, the objective of the Sea Musketeers is to inspire awe and curiosity for the oceans and highlight the opportunities it can provide to a younger audience in terms of adventure, economic resources and career paths.

CONTENTS

Our oceans are currently under threat from a host of human influences: climate change, overfishing and habitat loss, and now, microplastics. Since their introduction at the beginning of the 1900s, plastics have been finding their way into our oceans, where they persist, breaking into ever smaller pieces. While these microplastics now represent a major threat to the health of many marine ecosystems, they are a threat that we can all work to resolve.

This resource has been put together to educate students using the pioneering research into microplastics in the ocean at the University of Exeter and Plymouth Marine Laboratory.

It covers key scientific principles such as food webs, allows students to work scientifically by simulating the researchers' investigations, and encourages students to use their findings to have a wider impact.

It is our hope, that as students develop into adults, they will be able to provide solutions for microplastics as both professional and citizen scientists.

Dr Ceri Lewis
Senior Lecturer, Marine biology
University of Exeter

A resource by

[digital explorer]

with

University of Exeter

Funded by

NERC Science of the Environment

Science partner

PML Plymouth Marine Laboratory

Education partner

The Sea Musketeers

About Plankton, Plastics and Poo

Plankton, Plastics and Poo provides GCSE teachers and students with a means to develop scientific skills alongside an understanding of one of the most serious anthropogenic environmental threats: microplastics in the ocean. This resource has been funded by the Natural Environment Research Council (NERC) and developed in conjunction with some of the United Kingdom's leading marine researchers based at the University of Exeter and Plymouth Marine Laboratory led by Dr Ceri Lewis.

Plankton, Plastics and Poo focuses on working scientifically with opportunities for enquiry, literacy and developing a wider impact, highlighted throughout.

Learning journey

Dr Lewis' team has two hypotheses:

H_1: Zooplankton in the oceans eat microplastics.

H_2: Eating microplastic reduces natural food intake.

The students' learning journey will mirror that of a professional scientist. First, they conduct background research around the hypotheses. Next, they replicate Dr Lewis' experiment. They, then, analyse and make conclusions from their own experiments and actual data from the study. Finally, they consider how they could use their discoveries to have a wider impact, sharing their learning with their community and beyond.

To provide context, each stage is introduced by a brief from a member of the research team, complemented by a video and concluded with the scientists' reflections.

Making it matter

At the end of the project, students create an action plan to facilitate an impact beyond the classroom.

Careers

By mirroring the research journey of Dr Lewis' team and viewing the videos, students gain an insight into life as a professional scientist.

Assessment and feedback

The lessons provide regular opportunities for Assessment for Learning (AfL) throughout the lesson and towards the end with a summary assessment task. These include a range of assessment Student Sheets and extended written tasks.

Differentiation

Each lesson is differentiated by outcome, with learning and assessment tasks explicitly mapped to these throughout the resources; and to provide additional challenge, many of the worksheets have a 'higher' version. The outcomes are hierarchical to allow students to progress through them, described as follows:

Foundation	For students with a more limited understanding of science. (GCSE Grades 1-2)
Developing	Aimed at students who may need more support in science. (GCSE Grades 3-4)
Competent	Students consistently achieving the competent outcomes would be expected to meet the new international benchmark in formal exams. (GCSE Grade 5)
Expert	Aimed at students who are working above the new international benchmark. (GCSE Grades 6-7)
Advanced	Advanced outcomes go beyond the normal GCSE specification. (GCSE Grades 8-9)

Working scientifically

As they follow the same journey as Dr Lewis' team, students will have the opportunity to apply sampling techniques, make observations, carry out simple statistical analysis, present data, assess repeatability, draw conclusions and consider the wider implications of science.

Literacy in science

Students have the opportunity to practise a range of writing styles including writing to explain, analyse and conclude.

More oceans resources from Digital Explorer

Plankton, Plastics and Poo is complemented by other schemes of work for secondary age students, all of which can be downloaded for free from the Digital Explorer website.

Frozen Oceans KS3 and GCSE

The Frozen Oceans units of work outline the research carried out by the Catlin Arctic Surveys between 2009 and 2011 and can be used in teaching the carbon cycle, ocean acidification and its impact on the Arctic ecosystem for Science at KS3 and GCSE. In both projects, students work scientifically by using field data and using scientific discoveries to have a wider impact.
bit.ly/Res_oceans

Sustainable Fisheries

An enquiry-based scheme of work investigating the seas around the UK and EU. The lesson plans and activities cover why fish stocks are decreasing, the issues and impacts associated with overfishing, and marine ecosystems and sustainability. The activities examine different stakeholder views and use current data from the UN FAO, MMO and the New Economics Foundation.
bit.ly/DEReso

Coral Oceans KS3

These resources for ages 11-14 are based on the journeys undertaken by science teams taking part in the XL Catlin Seaview Survey expeditions seeking to create a baseline survey of the world's reefs. The lesson plans and accompanying activities are designed to introduce classes to what it is like to be an ocean explorer. Each lesson is designed around a 'dive' to investigate a particular science topic. These include identification, classification, food webs and symbiosis, adaptation and human impacts on the environment. The enquiry-based resources incorporate the scientists' experiences and research, and enable students to explore marine life on the reef and the threats facing it.
bit.ly/Res_oceans

SPECIFICATION LINKS (AQA)

Specification	Lesson 1 - Interdependence - The carbon cycle	Lesson 2 - Negative human impact on biodiversity	Lesson 3 - Waste management and pollution	Lesson 4 - Sampling	Lesson 5 - Presenting data - Processing data	Lesson 6 - Interpreting and concluding	Lesson 7 - Communicating wider implications of science
AQA Trilogy	4.7.1.1 Within a community each species depends on other species. 4.7.2.1 Feeding relationships within a community can be represented by food chains. 4.7.2.2 The carbon cycle returns carbon from organisms to the atmosphere as carbon dioxide to be used by plants in photosynthesis.	4.7.3.2 Pollution can occur in water, from sewage, fertiliser or toxic chemicals and on land, from landfill and from toxic chemicals such as pesticides and herbicides, which may be washed from land into water. Pollution kills plants and animals which can reduce biodiversity.	4.7.3.2 Pollution can occur in water, from sewage, fertiliser or toxic chemicals and on land, from landfill and from toxic chemicals such as pesticides and herbicides, which may be washed from land into water. Pollution kills plants and animals which can reduce biodiversity.	AT6 Application of appropriate sampling techniques to investigate.	WS 3.1 Present observations and other data using appropriate methods. WS 3.3 Carry out and represent mathematical and statistical analysis.	WS 3.5 Interpret observations and other data. WS 3.6 Present reasoned explanations including relating data to hypotheses.	WS1.4 Evaluate associated personal, social, economic and environmental implications. WS1.6 Recognise the importance of peer review of results and of communicating results to a range of audiences. WS 3.8 Communicate the scientific rationale for findings and reasoned conclusions through written and electronic reports and presentations.

Specification	Lesson 1 - Interdependence - The carbon cycle	Lesson 2 - Negative human impact on biodiversity	Lesson 3 - Waste management and pollution	Lesson 4 - Sampling	Lesson 5 - Presenting data - Processing data	Lesson 6 - Interpreting and concluding	Lesson 7 - Communicating wider implications of science
AQA Synergy	4.4.1.2 Explain the importance of the carbon cycle to living organisms. 4.4.2.2 Describe the importance of interdependence and competition in a community.	4.4.2.6 Describe negative human interactions within ecosystems and explain their impact on biodiversity.	4.4.2.6 Describe negative human interactions within ecosystems and explain their impact on biodiversity.	AT6 Application of appropriate sampling techniques to investigate.	WS 3.1 Present observations and other data using appropriate methods. WS 3.3 Carry out and represent mathematical and statistical analysis.	WS 3.5 Interpret observations and other data. WS 3.6 Present reasoned explanations including relating data to hypotheses.	WS1.4 Evaluate associated personal, social, economic and environmental implications. WS1.6 Recognise the importance of peer review of results and of communicating results to a range of audiences.

SPECIFICATION LINKS (OCR)

Specification	Lesson 1 - Interdependence - The carbon cycle	Lesson 2 - Negative human impact on biodiversity	Lesson 3 - Waste management and pollution	Lesson 4 - Sampling	Lesson 5 - Presenting data - Processing data	Lesson 6 - Interpreting and concluding	Lesson 7 - Communicating wider implications of science
OCR 21st Century	B3.3.5 Explain the importance of interdependence in a community. B3.3.7 Explain the importance of the carbon cycle to living organisms.	B6.3.1 Describe negative human interactions within ecosystems and explain their impact on biodiversity.	B6.3.1 Describe negative human interactions within ecosystems and explain their impact on biodiversity.	PAG B2 Application of appropriate sampling techniques to investigate.	IaS2.3 When displaying data graphically: a) select an appropriate graphical form, b) use appropriate axes and scales, c) plot data points correctly, d) draw an appropriate line of best fit, e) indicate uncertainty (eg range bars). IaS2.4 When analysing data: b) use statistics (range and mean), c) obtain values from a line on a graph (including gradient).	IaS2.7a Use data to make or justify a conclusion. IaS2.7b Explain the extent to which data increase or decrease confidence in a prediction or hypothesis.	IaS4.9 Suggest reasons why different decisions on the same issue might be appropriate in view of differences in personal, social, or economic context. IaS4.10 Explain why scientists should communicate their work to a range of audiences.
OCR Gateway	B4.1c Explain the importance of the carbon cycle to living organisms. B4.1f Describe the importance of interdependence in a community.	B6.1b Describe negative human interactions within ecosystems and explain their impact on biodiversity to include threats from hunting.	B6.1b Describe negative human interactions within ecosystems and explain their impact on biodiversity.	B6.1a Explain how to carry out a field investigation into distribution and abundance and how to determine numbers in a given area.	WS1.3a Present observations and other data using appropriate methods. WS1.3c Carry out and represent mathematical and statistical analysis.	WS1.3e Interpret observations and other data. WS1.3f Present reasoned explanations.	WS1.1f Evaluate associated personal, social, economic and environmental implications. WS1.1i Recognise the importance of peer review of results and of communicating results to a range of audiences.

Specification	Lesson 1 - Interdependence - The carbon cycle	Lesson 2 - Negative human impact on biodiversity	Lesson 3 - Waste management and pollution	Lesson 4 - Sampling	Lesson 5 - Presenting data - Processing data	Lesson 6 - Interpreting and concluding	Lesson 7 - Communicating wider implications of science
Edexcel	B9.3 Describe the importance of interdependence in a community. B9.4 Describe how the survival of some organisms is dependent on other species. B9.12 Explain the importance of the carbon cycle including the processes involved.	B9.8 Explain the positive and negative human interactions within ecosystems and their impacts on biodiversity.	B9.8 Explain the positive and negative human interactions within ecosystems and their impacts on biodiversity.	WS2e Recognise when to apply a knowledge of sampling techniques to ensure any samples collected are representative.	WS3a Present observations and other data using appropriate methods. WS3b Translate data from one form to another. WS3c Carry out and represent mathematical and statistical analysis.	WS3e Interpret observations and other data. WS3f Present reasoned explanations including relating data to hypotheses.	WS1c Evaluate associated personal, social, economic and environmental implications. WS1f Recognise the importance of peer review of results and of communicating results to a range of audiences.

Lesson 1: Why should we care about zooplankton?

Outline

In this lesson students learn the importance of zooplankton as primary consumers in the community and as part of the marine biological pump in the global carbon cycle. These zooplankton account for a staggering percentage of the Earth's biomass, and yet because they are microscopic and in the ocean, we hardly give them much thought.

Outcomes

Foundation	Say what zooplankton are.
Developing	Define and use a variety of ecological terms correctly to describe zooplankton.
	Draw food chains and pyramids of numbers with zooplankton.
Competent	Explain the importance of zooplankton in a community.
Expert	Explain the importance of zooplankton in the marine carbon cycle.

Resources

- Student Sheet 1a
  The importance of zooplankton
- Slideshow 1
- Video 1 Investigating the impact of microplastics
- Mark Scheme for Student Sheet 1a
- Subject Update 1
  Copepods
- Subject Update 2
  The marine carbon cycle

Specification Links

Interdependence and Carbon cycle

AQA Trilogy: 4.7 Ecology
AQA Synergy: 4.4 Explaining change
OCR 21: B3 Living together
OCR Gateway: B4 Community level systems
Edexcel: B9 Ecosystems and material cycles

Lesson 2: How can humans affect the marine environment?

Outline

The ocean is worth $49.7 trillion to the global economy and its beauty is priceless. People, every day, all over the world, use the ocean for a whole variety of purposes: but what impact does this human activity have on the ocean, the organisms that live there and on us?

Outcomes

Foundation	Give examples of human impacts.
Developing	Use the words 'overfishing' 'dose' and 'persistent' correctly.
	Describe what happens in a trophic cascade and apply this knowledge.
Competent	Describe the process of bioaccumulation.
Expert	Explain why it is difficult to predict the impact of population change.

Resources

- Student Sheet 2a
  Card sort for bioaccumulation
- Student Sheet 2b
  Human impacts summary
- Student Sheet 2c
  Human impacts summary (higher)
- Slideshow 2
- Answer Sheet for Student Sheet 2b
- Answer Sheet for Student Sheet 2c
- Subject Update 3
  Trophic cascades

Specification Links

Negative human impact on biodiversity

AQA Trilogy: 4.7 Ecology
AQA Synergy: 4.4 Explaining change
OCR 21: B6 Life on Earth
OCR Gateway: B6 Global challenges
Edexcel: B9 Ecosystems and material cycles

Make it Matter

Students could find out about which seafood pregnant women should avoid and why.

Lesson 3: What are microplastics and where do they come from?

Outline

In this lesson, students develop their understanding of how human actions can have a negative impact on the marine environment.
The context of this lesson is investigating the amount of microplastics that students use every day in personal hygiene products.

Outcomes

Foundation	Say what microplastic is. Give sources of microplastics.
Developing	Define and use the term 'microplastic' correctly.
Competent	Describe how to use sampling techniques. Apply sampling techniques.
Expert	Switch between multiples of units. Use standard form.

Resources

- Activity Overview 3
  How much microplastic?
- Technician Notes 3
  How much microplastic?
- Student Sheet 3a
  How much microplastic?
- Student Sheet 3b
  Microplastics summary worksheet
- Student Sheet 3c
  Hunting microplastic home learning
- Slideshow 3
- Subject Update 4
  Marine plastics
- Subject Update 5
  Marine plastics facts and figures

Specification Links

Waste management and pollution

AQA Trilogy: 4.7 Ecology
AQA Synergy: 4.4 Explaining change
OCR 21: B6 Life on Earth
OCR Gateway: B6 Global challenges
Edexcel: B9 Ecosystems and material cycles

Make it Matter

Encourage students to send their tweet for real, if they send it to @de_updates, @CezzaLew or @SciMatty we'll retweet it for them.

Students can conduct a survey at home to see which of their own personal hygiene products contain microplastic. Ideally, they would avoid buying these in the future.

Lesson 4: Do zooplankton and microplastics occur together?

Outline

In this lesson, students learn how to apply sampling techniques, using real field data collected by Dr Lewis' team. The context of this lesson is the voyage the team took to the Gulf of Maine to investigate if zooplankton and microplastics co-occur.

Outcomes

Foundation	Describe how to collect data at sea.
Developing	Define and use the key words correctly.
Competent	Apply sampling techniques.
Expert	Use standard form. Evaluate sampling techniques.

Resources

- Student Sheet 4a
  Do zooplankton and microplastics occur together?
- Student Sheet 4b
  Do zooplankton and microplastics occur together? (higher)
- Slideshow 4
- Video 2 Science under sail
- Answer Sheet for Student Sheet 4a
- Answer Sheet for Student Sheet 4b

Specification Links

Sampling techniques

AQA Trilogy: AT6
AQA Synergy: AT6
OCR 21: PAG B2
OCR GW: B6.1a
Edexcel: WS2e

Lesson 5: Do zooplankton eat microplastics? (Experiment set-up)

Outline

This lesson develops students' skills in data handling and presentation. Having learnt about microplastics and zooplankton separately, the next two lessons see students test the hypothesis that zooplankton eat microplastics. In this first lesson, students set up a classroom practical to collect primary data. They then process the secondary data collected by Dr Ceri Lewis and her team. In the next lesson, students will practise drawing conclusions from their own observations and Dr Lewis' data.

Outcomes

Foundation	Calculate differences and plot points on a graph accurately.
Developing	Calculate averages, choose appropriate graphs to draw, and draw your own scales on axes.
Competent	Handle anomalies, draw lines of best fit, and range bars.
Expert	Find linear equations.
Advanced	Calculate standard deviation.

Resources

- Activity Overview 5
  Do zooplankton eat microplastics?
- Technician Notes 5
  Do zooplankton eat microplastics?
- Student Sheet 5a
  Do zooplankton eat microplastics? Practical
- Student Sheet 5b
  Do zooplankton eat microplastics? Data analysis
- Slideshow 5
- Video 3 Science in the lab
- Answer Sheet for Student Sheet 5b

Specification Links

Mathematical and statistical analysis

AQA Trilogy: WS3.3
AQA Synergy: WS3.3
OCR 21: IaS2.4b, IaS2.4c
OCR Gateway: WS1.3c
Edexcel: WS3c

Presenting & transforming data

AQA Trilogy: WS3.1
AQA Synergy: WS3.1
OCR 21: IaS2.3a - e
OCR Gateway: WS1.3a
Edexcel: WS3a

Lesson 6: Do zooplankton eat microplastics? (Conclusions)

Outline

In this lesson, students return to their experiments from Lesson 5, and observe the gut contents of the brine shrimp, applying model conclusions to what they can see. Students develop their ability to write scientific conclusions using the secondary data from the research team. The lesson ends with students considering the implications of microplastics being consumed by zooplankton on a wide scale.

Outcomes

Foundation	Say what results show.
Developing	Describe patterns in results.
	Describe how results support hypotheses.
Competent	Explain your conclusion with science.
	Explain conclusions' wider impacts.
Expert	Support conclusions with numerical values.
	Describe the limitations of conclusions.

Resources

- Activity Overview 5
- Technician Notes 5
  Do zooplankton eat microplastics?
- Student Sheet 5a
  Do zooplankton eat microplastics? Practical
- Student Sheet 6a
  Model conclusions
- Student Sheet 6b
  Do zooplankton eat microplastics? Conclusions
- Slideshow 6
- Video 1 Investigating the impact of microplastics
- Answer Sheet for Student Sheet 6b

Specification Links

Interpreting and concluding

AQA Trilogy: WS3.5, WS3.6
AQA Synergy: WS3.5, WS3.6
OCR 21: IaS2.7a, IaS2.7b
OCR Gateway: WS1.3e, WS1.3f
Edexcel: WS3e, WS3f

Lesson 7: How can you make sure your discoveries have an impact?

Outline

Having made their discovery that microplastics affect zooplankton feeding and that this could have devastating environmental consequences, the question is, what changes do they want to see, and who should make them?

Outcomes

Foundation	Give some ways scientific discoveries can have an impact.
Developing	Produce and implement a small scale impact plan that reaches 1-2 people.
Competent	Produce and implement an impact plan that reaches 2-50 people.
Expert	Produce and implement a large scale impact plan that reaches 50 or more people.

Resources

Student Sheet 7a
Reducing the impacts of microplastics

Student Sheet 7b
Communications ideas

Student Sheet 7c
Impact plan

Student Sheet 7d
SMART targets

Slideshow 7

Video 4 Science and society

Specification Links

Wider impacts of science

AQA Trilogy: WS1.4
AQA Synergy: WS1.4
OCR 21: IaS4.9
OCR Gateway: WS1.1f
Edexcel: WS1c

Communicating science

AQA Trilogy: WS1.6
AQA Synergy: WS1.6, 3WS.8
OCR 21: IaS4.10
OCR Gateway: WS1.1i
Edexcel: WS1f

Make it Matter

Encourage students to follow through with their impact plans.
Prepare a lesson in a few weeks' where students share and evaluate their impacts.

RESOURCE GUIDANCE

The resources contained within this booklet are accompanied by further online resources available to download or stream freely.

Resources in this booklet
There are seven types of resource in this booklet to support teaching and learning for Plankton, Plastics and Poo:
Lesson Overview short overview of each lesson, with a basic outline and lesson steps, combined with a list of the available resources
Teacher Guidance detailed step-by-step teaching guidance for each lesson, referencing the Slideshows, Student Sheets and media resources to be used at different points during the lesson
Activity Overview more detailed guidance for teachers on a specific lesson activity, eg the practical activities
Technician Notes a list of resources and preparatory notes for your technician to set up practical activities
Student Sheet an activity sheet to be handed out to students as part of a lesson step
Answer Sheets answers to the exam style questions
Subject Updates background information for teachers to assist with their subject knowledge, these can also be used as student handouts where applicable

Resources online
There are five types of resource online to support teaching and learning for Plankton, Plastics and Poo:
Teacher Booklet a general overview of the project, containing schemes of work and background information bit.ly/PPP_TB
Slideshow each lesson has an accompanying slideshow that guides the learning bit.ly/PPP_SL
Media Zone videos and photos relating to the learning contained within Digital Explorer's bespoke web app, these can be accessed by students or used for independent study and flipped / blended learning approaches bit.ly/MZ_PPP
Explore Live live social and interactive media updates from researchers involved in the programme bit.ly/DEExplore

Teacher Guidance

The Teacher Guidance for each lesson uses a set of icons to provide visual cues to support teachers:

Lesson activities

Explain
teacher exposition using slides or script to support

Demonstration / watch
students watch a demonstration or video

Student activity
activity for students to complete individually, such as questions on a Student Sheet

Group work
activity for students to complete in pairs or small groups

Whole class discussion
teacher conducts a whole class discussion on a topic or as a plenary review

Teacher ideas and guidance

Assessment and feedback
guidance to get the most from Assessment for Learning (AfL)

Guidance
further information on how to run an activity or learning step

Idea
optional idea to extend or differentiate an activity or learning step

Information
background or further information to guide an activity or explanation

Technical
specific ICT or practical hints and tips

Health and safety

Health and safety
health and safety information on a specific activity

Access

Free and without registration.

Visit: media.digitalexplorer.com

Home learning

Students can browse and learn from the photo and video captions in their own time, making the Media Zone ideal for home learning.

Idea!

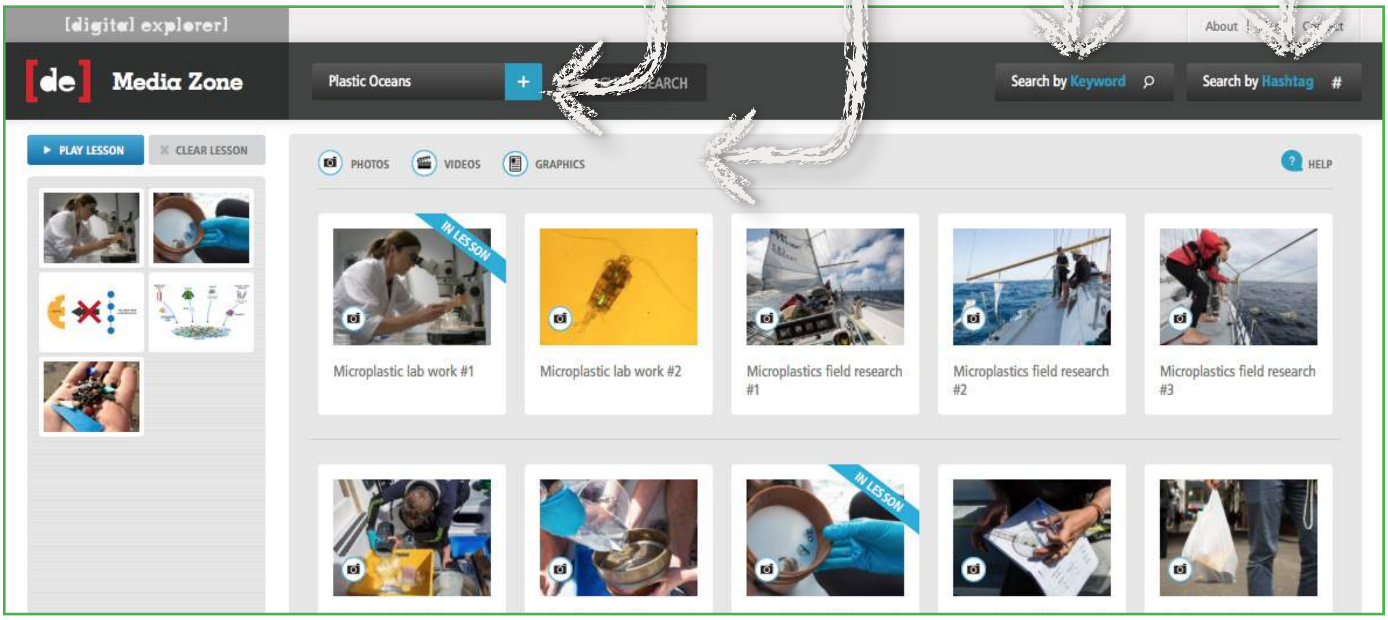
Students can browse and learn from the photo and video captions in their own time, making the Media Zone ideal for home and flipped learning.

Media Zone

The Media Zone lets you create sequences of photos and videos from the resources, bringing an easy-to-use multimedia element to lessons.

Search by:

Theme	Type	Keyword	Hashtag
Eg Plastic Oceans	Photo Video Graphics	Search function using keywords.	#microplastics #science at work #marine biology



Photos

High resolution photographs from expeditions and research, including:

Marine plastic pollution #1
Plastics can take 100s of years to break down completely. Until then it can confuse animals who may not be able to tell if it's food, a place to live or even another animal like them.

Videos

Short HD videos to explore research in the lab and the field, including:

Science under sail
In this video the research team provide an insight into field sampling techniques. Join them as they explain how to identify a research site and how to ensure that any samples collected can be used as valid data.

Graphics

High quality maps, graphs, and diagrams, including:

Microplastic sources
Each year 28 million tons of used plastic ends up in the ocean where they gradually break up into smaller and smaller fragments.

Overview

The plastics research project is currently ongoing, which gives students the opportunity to connect with the research team members, follow the project and ask questions via social media or through organising a video Skype lesson. The different ways of connecting to the research team are described below and brief biographies of the current members of the team are on page 17.

Interacting directly with the research team provides an opportunity for developing students research and questioning skills. What information can easily be found from an online search? What is the added benefit of speaking directly to a researcher? What kind of questions should we ask?

As a general rule, we ask that students prepare 'non-googleable' questions when in touch with the scientists. So rather than asking about the amount of plastics in the ocean, an answer that could be found online, students could think about asking what the most interesting part of the research has been; how to get a similar job; or how the research team think their research could have an impact on policy.

Follow the research

To follow the research programme, we would suggest the following:

- Follow the research team on twitter (see Twitter links on the next page)
- Follow the Digital Explorer blog http://digitalexplorer.com/tag/plastics
- You can also see updates from the University of Exeter Biosciences team at http://biosciences.exeter.ac.uk/news

Interact with the team

Live Events

All opportunities for live interaction with the research team will be listed on the Explore Live page: bit.ly/DEExplore

Twitter

To ask questions to the research team via twitter, you will first need a twitter account. If you haven't used Twitter before, you will need to sign up for an account at https://twitter.com/signup?lang=en.

Many teachers setting up a class account, use a combination of school initials and department or class. Examples for St Trinian's Science GCSE classes might be: STSciGCSE, TriniansSci10E or StTriniansSci. For class accounts, teachers tend to use the school logo as the profile photo or 'avatar'.

Once you have logged into Twitter, select one of the research team using the Twitter accounts listed on the next page. Remember to use the hashtag #planktonplastics, so the researchers know the tweet is part of this project.

Type a tweet, asking a question, eg '@CezzaLew what do you hope will be the impact of your research? #planktonplastics'.

The research team will reply as soon as they have time.

Skype in the classroom

The research team are also using the Skype in the classroom platform to speak to classes during the project. The Plankton & Plastics lesson is accessible via the Digital Explorer Microsoft Educator Community page http://bit.ly/DE_MEC.

The Basics

The first thing you will need is to register on the Microsoft Education Community and to have a Skype ID. You may already have Skype, but if not sign up at http://login.skype.com/account/signup-form.

Once you have a Skype ID you can join the Microsoft Educator Community at http://education.microsoft.com if you are not already a member.

Joining a Skype Lesson

Once you have signed into Microsoft Educator Community, select the Plastics and Plankton lesson at http://bit.ly/PPP_MEC.

To take part in a lesson, click on the 'Register' button.

Digital Explorer will then be in touch to schedule a time between you and the speaker.

Lesson opportunities are done on a first come, first served basis. Our speakers often have a limited amount of time to take part in Skype lessons and so you may not be successful first time around.

If you haven't heard anything back, you can always contact Digital Explorer by email at info@digitalexplorer.com.

Equipment you will need

You will need a good internet connection, especially if you want to do a video call.

You can Skype from a range of devices - desktop, laptop, tablet or mobile - but will need to make sure that you have a good enough webcam, microphone and speakers. Many devices now have these built in.

If you don't have Skype installed on your device, you can download it from http://skype.com/en/download-skype/.

It would also help to have a digital projector and decent audio speakers, so that the whole class is able to see and hear the discussion.

Preparing for your lesson

Many Skype guest speakers ask that students prepare questions in advance for the lesson.

Try to ensure that these questions are non-googleable and that students have done some research before the lesson. Try to make contact with the speaker prior to the lesson, and even try a practice call to make sure that the technology works. This will reduce any nerves at the time of the lesson. It will also allow time to discuss the format of the lesson and any resources that might be useful.

PLASTIC OCEANS RESEARCH TEAM

Dr Ceri Lewis, Senior Lecturer in Marine Biology, University of Exeter

Ceri Lewis is an experienced marine biologist with expertise in how environmental change and pollution affects reproductive processes in marine animals. Ceri holds a lectureship position at the University of Exeter and is conducting research into how marine animals adapt and respond to environmental change, such as ocean acidification, climate change and increasing pollution. Ceri joined the Catlin Arctic Survey in 2010 and 2011 to study ocean acidification in the High Arctic, enduring temperatures as low as -40°C. She recently did a research cruise into marine microplastics off the coast of Maine from a 60ft yacht.

@CezzaLew

Dr Matthew Cole, NERC Associate Research Fellow, University of Exeter

Matt's research interests relate to the impact of anthropogenic pollutants on aquatic environments. He graduated with a first class honours degree in Biosciences from the University of Exeter in 2008, and subsequently undertook an MSc in Aquatic Biology and Resource Management during which he developed a keen interest in eco-toxicological research. For his PhD he investigated the impacts of microplastic debris on marine zooplankton. He is currently working with the University of Exeter and Plymouth Marine Laboratory on a NERC funded project considering the biological and ecological impacts of microplastics in the marine environment.

@SciMatty

Dr Pennie Lindeque, Molecular Ecologist, Plymouth Marine Laboratory

Pennie Lindeque is a senior scientist with 18 years expertise in the area of development, systematics and trophic interactions of eukaryotes, in particular zooplankton. As a molecular biologist her research has centred on using molecular techniques to help answer ecological questions. This has included conducting feeding experiments and molecular gut content analysis.

@PlymouthMarine

Adam Porter, PhD Student, University of Exeter

Adam is working within the ecotoxicology team at the University of Exeter looking at what factors affect the bioavailability and uptake of plastics into marine biota. He has undertaken three research cruises to collect novel data from the mid-Atlantic and the North Sea, and has been undertaking a number of experiments in the laboratory. His hope is to ground truth laboratory data with fieldwork and to test hypotheses of how plastic behaves in the marine environment and how they affect marine biota with a range of laboratory experiments.

@ap3489

Prof Tamara Galloway, Professor of Ecotoxicology, University of Exeter

Tamara Galloway is a Professor of Ecotoxicology at the University of Exeter, UK. Her work focuses on understanding the biological effects of environmental pollutants to human and wildlife populations, focusing on the marine environment. She studies the harmful impacts of marine pollutants, including oil spills, novel substances and waste products, such as microscopic plastic litter (microplastic). Tamara receives funding from a wide range of competitive sources and advises governments internationally on environmental protection. She has published around 200 peer reviewed scientific articles, book chapters and popular science articles.

Lesson 1:
Why should we care about zooplankton?

In this lesson, students learn the importance of zooplankton as primary consumers in the community and as part of the marine biological pump in the global carbon cycle. These zooplankton account for a staggering percentage of the Earth's biomass, and yet because they are microscopic and in the ocean, we hardly give them much thought.

Resources in this booklet:

- Lesson Overview 1
- Teacher Guidance 1
- Student Sheet 1a The importance of zooplankton
- Mark Scheme for Student Sheet 1a
- Subject Update 1 Copepods
- Subject Update 2 The marine carbon cycle

Resources available online:

- Slideshow 1 available at bit.ly/PPP_SL
- Video 1 Investigating the impact of microplastics available at bit.ly/PPP_Vid1

LESSON 1: WHY SHOULD WE CARE ABOUT ZOOPLANKTON?

Lesson overview

In this lesson, students learn the importance of zooplankton as primary consumers in the community and as part of the marine biological pump in the global carbon cycle. These zooplankton account for a staggering percentage of the Earth's biomass, and yet because they are microscopic and in the ocean, we hardly give them much thought.

Details

Time
60 minutes

Specification links
Interdependence & Carbon cycle
AQA Trilogy: 4.7 Ecology
AQA Synergy: 4.4 Explaining change
OCR 21: B3 Living together
OCR Gateway B4: Community level systems
Edexcel: B9 Ecosystems and material cycles

Age
14-16 / GCSE Biology / GCSE Combined Science

Key words

Names	carnivore, community, consumer, herbivore, individual, phytoplankton, population, producer, zooplankton
Processes	decay, elimination, fossilisation, photosynthesis, respiration
Concepts	energy, trophic level

Lesson steps / Learning outcomes

Lesson steps	Learning outcomes
1 (10 mins) **Brief from Dr Ceri Lewis** Use the slides to set the context and share the learning outcomes. Engage students using the slides with the 'Animals in numbers' quiz.	Understand the wider context and learning outcomes.
2 (15 mins) **Ecological terms** Using the slides, students recap a variety of key ecological terms and diagrams. Assess student knowledge using the slide based 'Red, Yellow, Green' game.	**Foundation** Say what zooplankton are. **Developing** Define and use a variety of ecological terms correctly to describe zooplankton. Draw food chains and pyramids of numbers with zooplankton.
3 (20 mins) **Zooplankton in food webs and the carbon cycle** Use the video to stimulate students' ideas about the importance of zooplankton. Using Student Sheet 1a, students develop their understanding of food webs and the carbon cycle.	**Competent / Expert** Explain the importance of zooplankton in a community and in the marine carbon cycle.
4 (10 mins) **Exam style question** Students demonstrate their learning by answering a long answer question from the slide.	Demonstrate learning.
5 (5 mins) **Self-reflection** Using slides, students consider how alternative 'teachers' may have delivered the lesson.	Reflect on learning.

Resources

Student Sheet
Student Sheet 1a
The importance of zooplankton

Slideshow
Slideshow 1
Why should we care about zooplankton?

Videos
Video 1
Investigating the impact of microplastics

Answer Sheet
Mark Scheme
for Student Sheet 1a

Subject Updates
Subject Update
Copepods

Subject Update
The marine carbon cycle

Home learning

Students improve their long answer.

Flip it

Ask students to watch the video prior to the lesson and answer the questions on one of the video worksheets

Differentiation

By outcome
The open summary assessment task allows students to demonstrate their learning at any level.

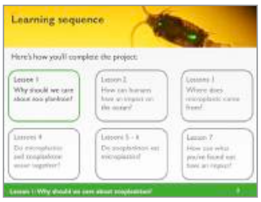
By support
See the Teacher Guidance for more ideas.

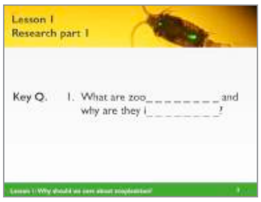
TEACHER GUIDANCE 1: WHY SHOULD WE CARE ABOUT ZOOPLANKTON?

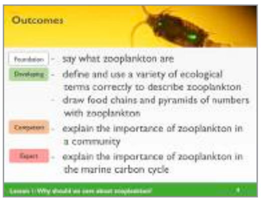
Step

1

10 mins







Contextualising learning
The purpose of Step 1 is to share the learning outcomes, set the context and engage students with the learning.

Read the topic brief from Dr Ceri Lewis on **Slide 1** to put the lesson into context. Use **Slide 2** to outline the learning sequence in the topic.

This is a good opportunity for students to take the lead and practise reading aloud.

Ask students to write the lesson title from the top left of **Slide 3**, as well as the date and key question into their books. They can then try to guess the missing words from the key question, which in this case are "*plankton*" and "*important*".

Read the outcomes on **Slide 4** with the students and ask them to put their hands up to show what they can already do.

Challenge students who you think are over or underestimating their current learning by asking targeted questions.

To pique student interest, use the 'Animals in numbers' quiz on **Slide 5**.

The answers follow on **Slides 6–7**.

2

15 mins

Developing ideas: ecological terms
The purpose of Step 2 is to recap some key ecological principles and vocabulary from Key Stage 3 and for students to learn what zooplankton are.

Use **Slide 8** to explain what zooplankton are with the example of a copepod.

The word plankton has the same route as the word planet: the Greek word '*planáo*' meaning 'I wander'.

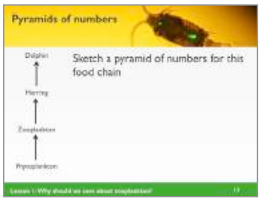
Ask students to draw a food chain in their book from the organisms on **Slide 9**. You will need to explain that 'phytoplankton' are small plant like organisms and include 'algae'.
Show students the correct chain on **Slide 10**.
Highlight that the arrows show the flow of energy.

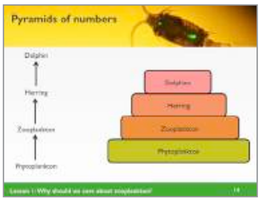
Many students erroneously think that the arrows show the action of the predator. One of the best ways for them to remember the correct direction of the arrows is that food goes **into** their mouths.

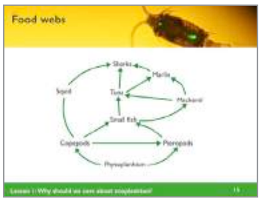
Show students the food chain on **Slide 11**. Emphasise each of the key terms, but do not explain their meaning at this point.
Ask students to work in pairs to discuss the questions on **Slide 12**. Go through the answers. Ask students to make notes of any term they were unsure of. These terms are found in the student version of the glossary.

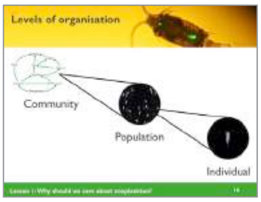
Students will be more confident using the term 'trophic' if they understand that it means 'feeding'. A good way to do this is to point out that it sounds similar to a 'trough' that farm animals eat from.

Step









Ask students to draw a pyramid of numbers in their book from the food chain on **Slide 13**.
Show students the correct pyramid on **Slide 14**.
Correct any misconceptions regarding the shape.

Marine pyramids can be a little unusual. Pyramids of biomass can even be inverted due to the high reproductive rate of phytoplankton. However, the pyramids of energy still to conform to classical shapes.

Show students **Slide 15–16** to illustrate zooplankton in a community and remind them of the ecological levels of organisation.

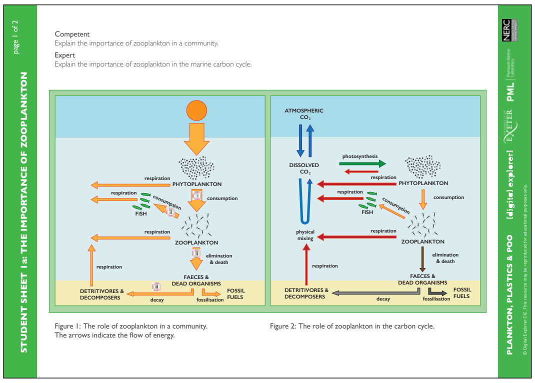
Learning check point (Assessment for Learning).

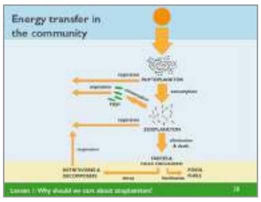
Use the 'Red, Yellow, Green' slides (**Slides 17-27**) and traffic light cards to assess students' understanding of zooplankton and key ecological terms.

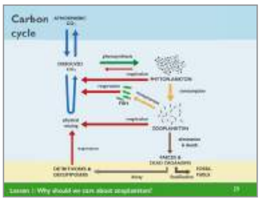
For students who make mistakes, ask them the same questions later on in the lesson to check for recall.

3

20 mins







Developing ideas: role of zooplankton
The purpose of Step 3 is for students to understand the significance of zooplankton on a community scale, as a food source, and on a global scale as part of the biological pump in the marine carbon cycle.

Show students **Video 1** (bit.ly/PPP_Vid1)
Discuss students' initial ideas about the role of zooplankton in a community and in the carbon cycle.

Video 1 can also be set as home learning to watch before the lesson. The two relevant Student Sheets are linked in the video description or can be found in the Video Lessons section of the Resources Booklet or as a separate download from bit.ly/PPP_VA. One is a simple recall activity, the other takes a more reflective approach to learning from videos. An Answer Sheet for the recall questions is also included.

Hand out **Student Sheet 1a**, one between two. Using the diagrams, students work in small groups to discuss the learning task questions which help them build a picture of the importance of zooplankton.
Use the same diagrams from the worksheet on **Slides 28-29** to take feedback from the class.

Students do not need to answer the long question in the summary assessment task yet. They will be completing this in step 4.

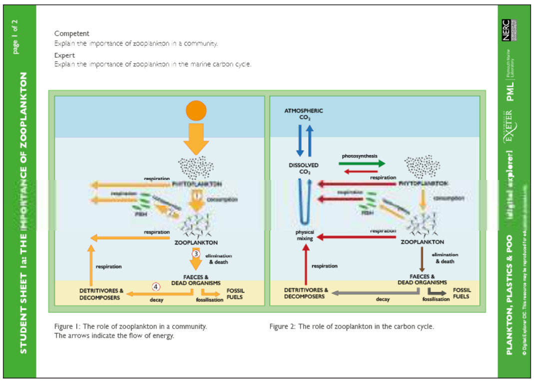
Learning check point (Assessment for Learning).

Use spot questions to assess students' understanding of the importance of zooplankton.

Step

4

10 mins



Demonstrating learning: exam style question
The purpose of Step 4 is for students to demonstrate their learning from this lesson and practise answering long answer questions.

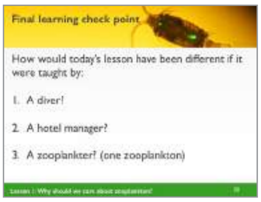
In timed conditions (10 minutes) students complete the long answer question in the summary assessment task section on **Student Sheet 1a**. Encourage them to plan their answers rather than jumping straight in.
Display the **Mark Scheme** on the board. Ask students to use this to peer mark their partner's answers. They should give a positive comment and an area to improve.

For home learning, students could be asked to redraft their answer in timed conditions.

Alternatively, you could hand out copies of the **Mark Scheme** and ask students to peer assess another student's answer for home learning. You can then go through this together at the start of next lesson. This is a good opportunity for students to understand how they will score marks in formal exams.

5

5 mins



Reflecting on learning
The purpose of Step 5 is for students to reflect on their learning and place it back into context with final thoughts from Dr Lewis.

Final learning check point (Assessment for Learning).

Ask students to complete the reflection questions on **Slide 30**. Take feedback from the class.

Round off the lesson by reading Dr Lewis' final thoughts on **Slide 31**.

Competent
Explain the importance of zooplankton in a community.

Expert
Explain the importance of zooplankton in the marine carbon cycle.

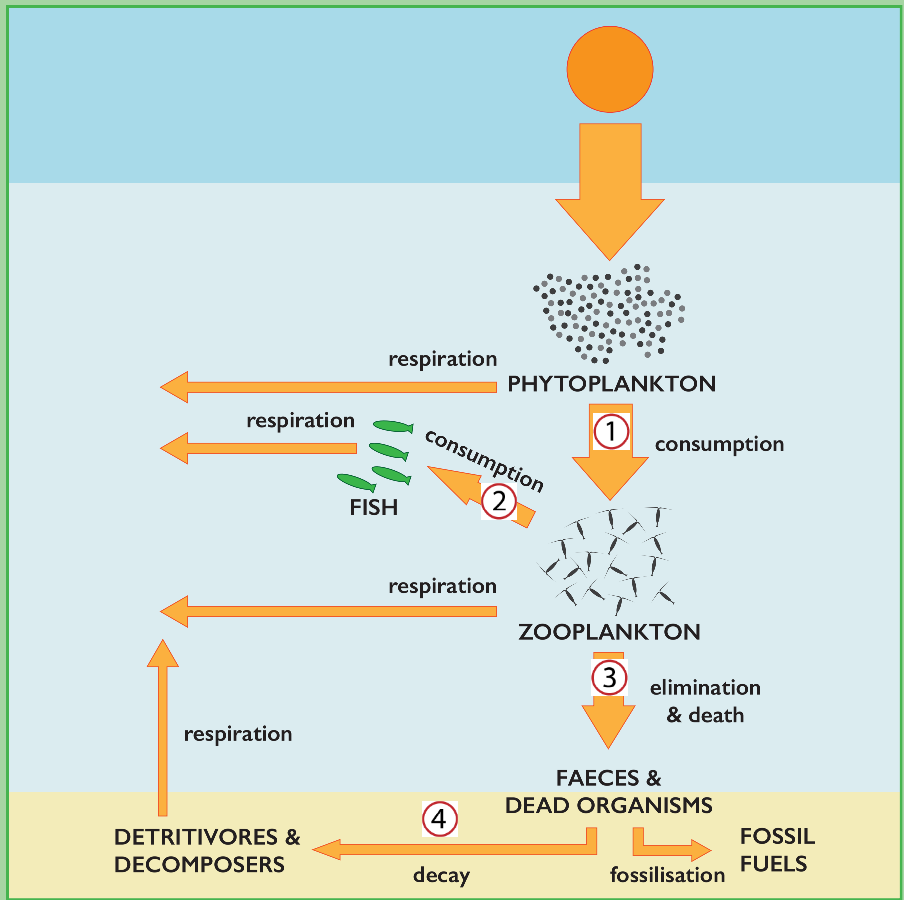


Figure 1: The role of zooplankton in a community.
The arrows indicate the flow of energy.

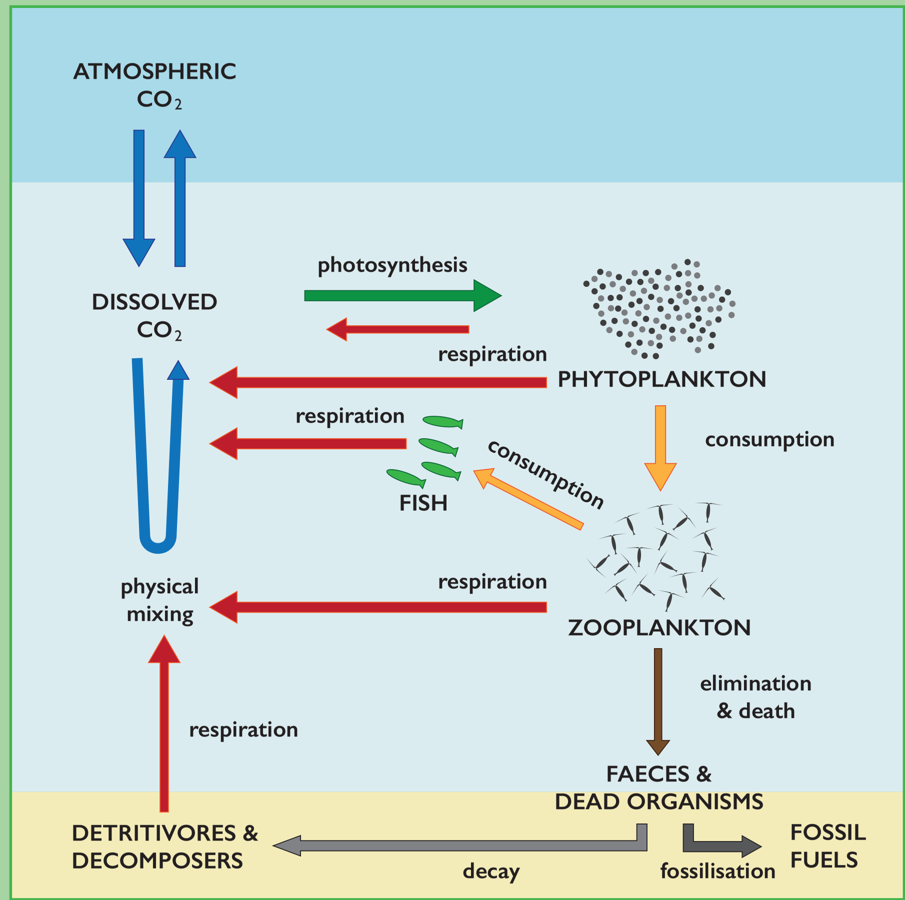


Figure 2: The role of zooplankton in the carbon cycle.

STUDENT SHEET 1a: THE IMPORTANCE OF ZOOPLANKTON

Learning Tasks

Discuss these questions with your group.

1. Look at Figure 1.

    a. What does arrow 1 represent?
    b. What does arrow 2 represent?
    c. Look at arrows 3 and 4. What do 'detritivores' eat?!
    d. What would happen to the other organisms if there were no zooplankton in this food chain?
    e. How are zooplankton important to this community?

2. Look at Figure 2.

A 'carbon sink' is something that takes carbon dioxide out of the atmosphere and locks it away for a long time. For example, trees are carbon sinks, because they use carbon to produce wood. We say that the carbon has been 'stored' in the wood.

    a. Why is the amount of carbon dioxide in the atmosphere important?
    b. In the diagram, where is carbon dioxide being locked away?
    c. How does it 'get' there?
    d. This system is called the 'biological pump', why?
    e. How are zooplankton important in the carbon cycle?
    f. If there were no zooplankton, what might happen in the carbon cycle?

Summary Assessment Task

Answer this question in your book.
Explain how zooplankton are important in their community and globally. (6 marks) *You will be marked on your quality of written communication.*

MARK SCHEME FOR STUDENT SHEET 1a

Question

Explain how zooplankton are important in their community and globally. *You will be marked on your quality of written communication.*

Mark Scheme

Marks	Literacy	Content guidance	Points to include
1-2	**Step 1** - Many spelling errors. - Full stops and capitals rarely used correctly. - Answer is not well organised. - Some science vocabulary is used.	Candidate can give general reasons why zooplankton are important: Any TWO points made from any area.	**Area 1: Importance as a direct source of energy in the community** - Phytoplankton capture energy (from the sun) in photosynthesis. - Energy (from the sun) passes into zooplankton when they eat phytoplankton. - Energy (from the sun) passes into other organisms when they eat the zooplankton. - The faeces are a source of energy to detritivores. **Area 2: Importance as a part of the biological pump** *The points below could be made as a diagram.* - Carbon dioxide can affect global climate / temperature / cause global warming. - Phytoplankton capture CO_2 / carbon (from the atmosphere / ocean) through photosynthesis. - Carbon passes into zooplankton when they eat phytoplankton. - There is carbon in the faeces excreted / eliminated / egested by zooplankton. - Faeces sink to the bottom of the ocean. - Faeces can become fossilised / become fossil fuels. - Fossilisation locks the carbon away / fossil fuels are a carbon sink.
3-4	**Step 2** - Some spelling errors. - Full stops and capitals used correctly. - Answer covers most of the major points, but may not be logically organised. - Good use of science vocabulary.	EITHER: Candidate can give partial explanations as to why zooplankton are important OR: they can give one detailed explanation EITHER: TWO points from both areas OR: FOUR linked points from ONE area.	
5-6	**Step 3** - Few spelling errors. - Good use of punctuation. - If a diagram is used, it is presented clearly. - Answer divided into sensible paragraphs. - Answer flows in a logical order. - Large variety of science vocabulary is used.	Candidate can give detailed explanations as to why zooplankton are important: At least THREE linked points from Area 1 and at least THREE linked points from Area 2.	

Lesson 2:
How can humans affect the marine environment?

The ocean is worth $49.7 trillion per year to the global economy and its beauty is priceless. People, every day, all over the world, use the ocean for a whole variety of purposes: but what impact does this human activity have on the ocean, the organisms that live there and on us?

Resources in this booklet:

Lesson Overview 2
Teacher Guidance 2

Student Sheet 2a Card sort for bioaccumulation
Student Sheet 2b Human impacts summary
Student Sheet 2c Human impacts summary (higher)

Answer Sheet for Student Sheet 2b
Answer Sheet for Student Sheet 2c

Subject Update 3 Trophic cascades

Resources available online:

Slideshow 2 available at bit.ly/PPP_SL

LESSON 2: HOW CAN HUMANS AFFECT THE MARINE ENVIRONMENT?

Lesson overview

The ocean is worth $49.7 trillion per year to the global economy and its beauty is priceless. People, every day, all over the world, use the ocean for a whole variety of purposes: but what impact does this human activity have on the ocean, the organisms that live there and on us?

Details

Time
60 minutes

Specification links
Negative human impact on biodiversity
AQA Trilogy: 4.7 Ecology
AQA Synergy: 4.4 Explaining change
OCR 21: B6 Life on Earth
OCR Gateway: B6 Global challenges
Edexcel: B9.8 Ecosystems and material cycles

Age
14-16 / GCSE Biology / GCSE Combined Science

Key words

Processes	bioaccumulation, overfishing, trophic cascade
Concepts	dose, persistent

Lesson steps / Learning outcomes

Step	Lesson steps	Learning outcomes
1 (5 mins)	**Brief from Dr Pennie Lindeque** Use the slides to set the context and share the learning outcomes.	Understand the wider context and learning outcomes.
2 (5 mins)	**Human impact** Using the slides students discuss how humans can damage the marine environment. Highlight the two we will consider in the lesson: reducing populations and discharging chemical waste.	**Foundation** Give examples of human impact.
3 (10 mins)	**Trophic cascades** Using the slides, students consider the impact of changing the size of populations in food chains and webs. Learning check point: slide based questions.	**Developing** Describe what happens in a trophic cascade. **Expert** Explain why it is difficult to predict the impact of population change.
4 (20 mins)	**Bioaccumulation role play** Students learn about bioaccumulation through role play and 'paper poison'. Learning check point: stepping stone activity.	**Developing** Use the word persistent correctly. **Competent** Describe the process of bioaccumulation.
5 (15 mins)	**Summary assessment worksheet** Students demonstrate their learning by answering questions on Student Sheet 2b or 2c.	Demonstrate learning.
6 (5 mins)	**Self-reflection** Using slides, students consider how alternative 'teachers' may have delivered the lesson.	Reflect on learning.

Resources

Student Sheet

Student Sheet 2a
Card sort for bioaccumulation

Student Sheet 2b
Human impacts summary

Student Sheet 2c
Human impacts summary (higher)

Slideshow

Slideshow 2
Human impact on the marine environment

Answer Sheet

Answer Sheet for Student Sheet 2b

Answer Sheet for Student Sheet 2c

Subject Updates

Subject Update 3
Trophic cascades

Home learning

Students improve one of their answers.

Flip it
Ask students to view the plastic pollution images in the Media Zone prior to the lesson. Ask them to make a list of the problems humans can cause in the marine environment.

Differentiation

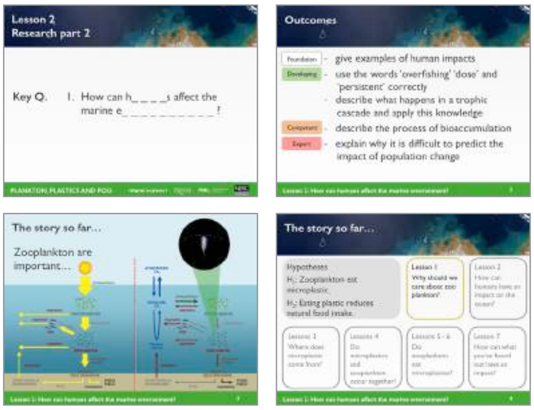
By task
To support students who may struggle, focus on trophic cascades. Use Student Sheet 2b to assess their learning.
To challenge higher ability students, focus on using knowledge to analyse data. Use Student Sheet 2c to assess this.

TEACHER GUIDANCE 2: HOW CAN HUMANS AFFECT THE MARINE ENVIRONMENT?

Step

1

5 mins



Contextualising learning
The purpose of Step 1 is to share the learning outcomes, set the context and engage students with the learning.

Ask students to write the lesson title from the top left of **Slide 1** as well as the date and key question into their books. They can then try to guess the missing words from the key question, which in this case are *"humans"* and *"environment"*. Emphasise the silent 'n' in environment.

Read the outcomes on **Slide 2** with the students and ask them to put their hands up to show what they can already do.

Link this lesson to previous learning using **Slides 3 and 4**.

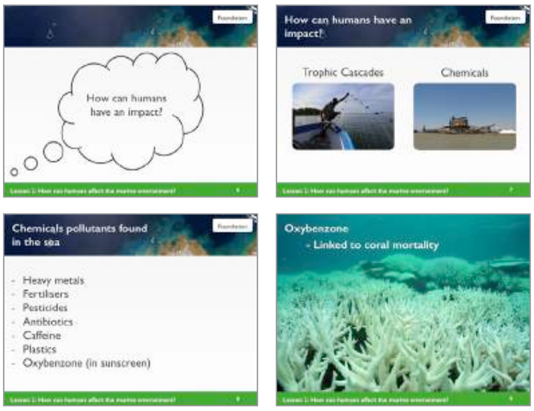
Read the topic brief from Dr Pennie Lindeque on **Slide 5** put the lesson into context.

Challenge students who you think are over or underestimating their current learning by asking targeted questions.

This is a good opportunity for students to take the lead and practise reading aloud.

2

5 mins



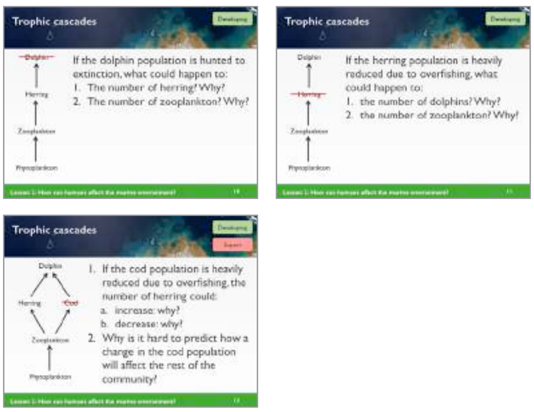
Developing ideas: human impacts
The purpose of Step 2 is to assess students' current understanding of human impact on the marine environment and to introduce the two threats they will study in this lesson: trophic cascades and chemical waste.

Show students **Slide 6** and ask them to discuss in pairs how humans could have an impact on the marine environment. Take feedback from the class, before showing them **Slides 7-9** which introduce two key impacts: trophic cascades and chemical waste.

You do not need to go into detail about how these chemicals have an impact. Bioaccumulation will be covered later in this lesson.
If you're teaching OCR 21 or Edexcel you could mention eutrophication here.

3

10 mins

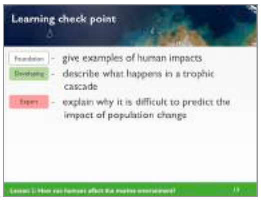


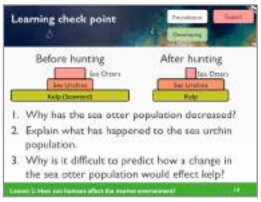
Developing ideas: Trophic cascades
The purpose of Step 3 is for students to understand that overfishing can cause trophic cascades, but that this is unpredictable due to the complexity of marine communities.

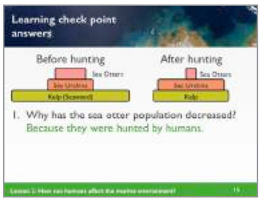
Show students **Slide 10**. Ask them to discuss the potential impact on the food chain of dolphins becoming extinct. Take feedback from the class. Explain that the change in other populations is known as a 'trophic cascade'.
Repeat this with **Slide 11** where the herring have been over fished. **Slide 12** introduces a food web. Ask students to discuss the questions. When taking feedback, highlight the difficulty in predicting due to the complex relationships within the community.

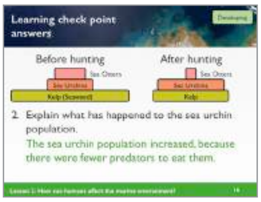
For more details on trophic cascades, see **Subject Update 3 Trophic cascades.**

Step









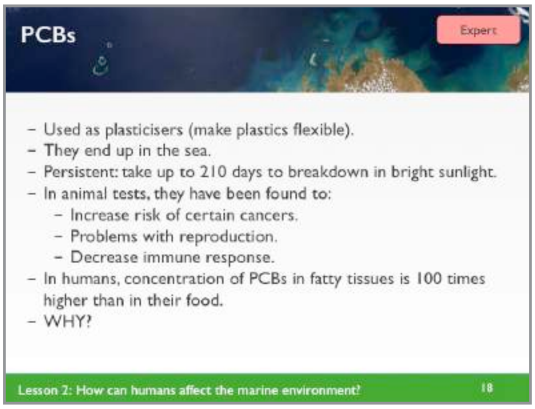
Learning check point (Assessment for Learning).

Remind students of the learning outcome on **Slide 13**.
Students answer the questions on **Slide 14**.
Students can self-mark the answers using **Slides 15-17**.

For students who make mistakes, ask them the same questions later in the lesson to check for recall.

4

20 mins



Developing ideas: bioaccumulation
The purpose of Step 4 is for students to understand the process of bioaccumulation.

Put the activity into context using **Slide 18** to introduce PCBs: a class of persistent chemical that bioaccumulates.

To explain the process of bioaccumulation, use role play. The aim of this is to first refresh students' memories of pyramids of numbers, before using this to demonstrate the build-up of chemicals using red paper as doses of poison.
Before you start:

- Make sure you have four spaces in your lab where several students could stand in a group.
- Prepare your doses of poison by cutting red paper into about 30 pieces.

Running the activity

1. First ask for one student volunteer. Ask them to stand and move into a space in the class room. Explain that they are now a dolphin.
2. Ask the student what its prey are (fish), and how many they think they could eat in a short time (two to three is reasonable).
3. Ask them to pick their prey from the other students in the class.
4. These 'fish' students stand together, but separately from the 'dolphin' student.
5. Ask the 'fish' to choose two to three students to be their zooplankton prey. These 'zooplankton' students should stand together, but separately from the 'dolphin' and 'fish'.
6. Finally, ask the 'zooplankton' to choose two to three students to be their phytoplankton food: who again stand together to a separate space in the room.
7. At this point, most of the class will be involved.
8. Explain that PCBs are run off the land, into the water. The red paper, represents individual doses of PCB. A dose is a certain amount of the chemical.
9. Hand the doses to the 'phytoplankton'.
10. Ask the 'zooplankton' to 'eat' the phytoplankton. The phytoplankton should hand over their doses of the chemical and then return to their seats.

Step

11. Ask the 'zooplankton' how many doses of PCBs they have. Introduce the term 'higher dose' and link it to the number of 'phytoplankton' they 'ate'.
12. Repeat this with the 'fish' and finally the 'dolphin'.

Consolidate students understanding of bioaccumulations using the diagram on **Slides 19 and 20**.

Reviewing these slide allows students to settle in between two kinaesthetic activities.

Learning check point (Assessment for Learning).

To assess students learning, use the stepping stones activity (print **Slides 24-30**).

Before you start:

- Make sure you have a clear space, you need enough space for the students to stand in a circle about 2 students deep.
- Place the A4 paper stones on the floor in a circle in a random order, the bottom of the page should face the middle.
- Securely tape the top and bottom of the page, this is to ensure the paper doesn't move when students step on it.

Running the activity

1. Ask students to gather around the stepping stones.
2. Tell them that the "stones" are safe to step on, but the clear space is shark infested water! They have to step on the stones in the correct order to get around the water.
3. Explain that the order is a sensible way of explaining bioaccumulation.
4. Ask students to look at the stones and decide which order they would step on them in. Allow between 30 seconds and a minute to do this.
5. Pick one student and ask them to stand on their first stone.
6. Ask them to describe what happens on this stone. For example:

"Chemicals get into the sea when they run off of the land."

7. Ask them to move to their next stone.
8. Ask them how they could link the two stones together with a connecting phrase.

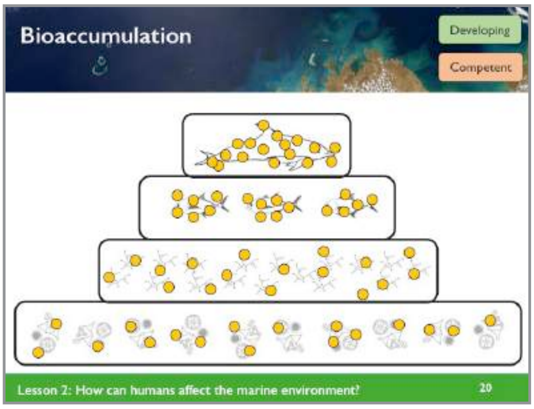
"Chemicals get into the sea when they run off of the land."

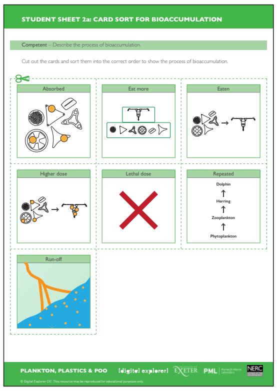
"Where…"

"They are absorbed by phytoplankton."

9. Ask them to move to the next stone and the next until they finish.

Step





10. As each stage use questioning to help students describe the events and link them.
11. Ask the student to go back to the beginning and describe the sequence from beginning to end.
12. Once they have finished, allow other students to have a go.

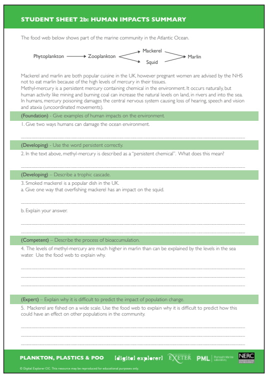
An example of a correct sequence would be
1. Run-off
2. Absorbed
3. Eaten
4. Eat more
5. Higher dose
6. Repeated
7. Lethal dose

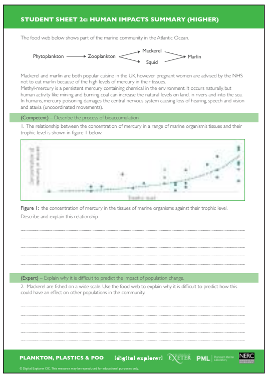
Students who are struggling will edge to the back, look for these and specifically choose them to have a go.
To provide help for these students, allow them three "life lines" where they can ask a peer for help.
To provide extra challenge for more able students, ask them to start at the end of the sequence and explain it backwards.

Alternatively, hand out **Student Sheet 2a** and ask students to complete the card sort.
The answers are on **Slide 21**.

5

15 mins





Demonstrating learning: Summary assessment worksheet
The purpose of Step 5 is for students to demonstrate their learning from this lesson.

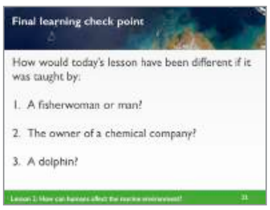
Hand out **Student Sheet 2b** or **2c (higher)** and ask students to complete the summary questions.
Display the **Answer Sheets** on the board. Ask students to use this to peer mark their partner's answers. They should give a positive comment and an area to improve.

For home learning, students could be asked to re-draft one of their answers in timed conditions.

Alternatively, you could hand out copies of the **Answer Sheets** and ask students to peer assess another students answer for home learning. You can then go through this together at the start of next lesson. This is a good opportunity for students to understand how they will score marks in formal exams.

6

5 mins



Reflecting on learning
The purpose of Step 6 is for students to reflect on their learning and place it back into context.

Final learning check point (Assessment for Learning).

Ask students to complete the reflection questions on **Slide 22**. Take feedback from the class.

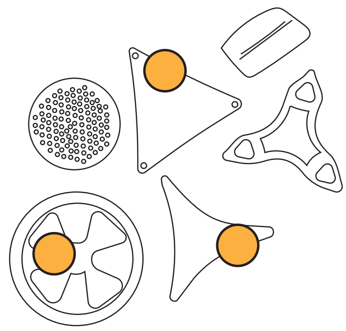
Round off the lesson by reading Dr Lindeque final thoughts on **Slide 23**.

STUDENT SHEET 2a: CARD SORT FOR BIOACCUMULATION

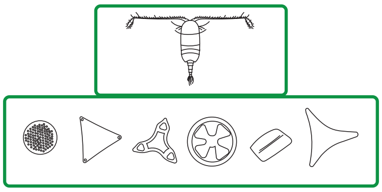
Competent – Describe the process of bioaccumulation.

Cut out the cards and sort them into the correct order to show the process of bioaccumulation.

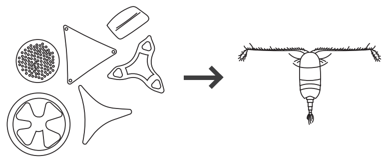
Absorbed



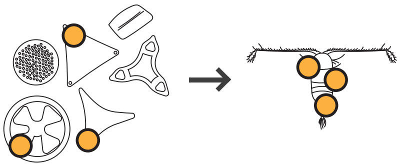
Eat more



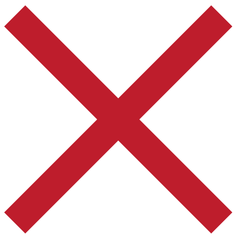
Eaten



Higher dose



Lethal dose



Repeated

Dolphin

↑

Herring

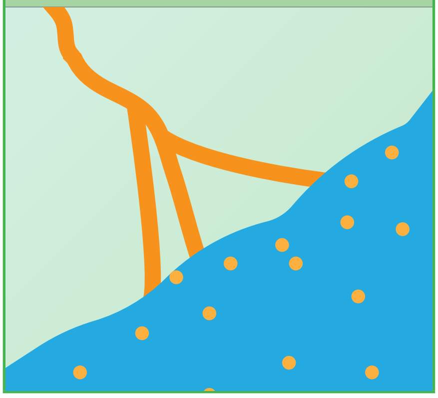
↑

Zooplankton

↑

Phytoplankton

Run-off



STUDENT SHEET 2b: HUMAN IMPACTS SUMMARY

The food web below shows part of the marine community in the Atlantic Ocean.

Mackerel and marlin are both popular cuisine in the UK, however pregnant women are advised by the NHS not to eat marlin because of the high levels of mercury in their tissues.
Methyl-mercury is a persistent mercury containing chemical in the environment. It occurs naturally, but human activity like mining and burning coal can increase the natural levels on land, in rivers and into the sea. In humans, mercury poisoning damages the central nervous system causing loss of hearing, speech and vision and ataxia (uncoordinated movements).

(Foundation) - Give examples of human impacts on the environment.

1. Give two ways humans can damage the ocean environment.

(Developing) - Use the word persistent correctly.

2. In the text above, methyl-mercury is described as a "persistent chemical". What does this mean?

(Developing) – Describe a trophic cascade.

3. Smoked mackerel is a popular dish in the UK.
a. Give one way that overfishing mackerel has an impact on the squid.

b. Explain your answer.

(Competent) – Describe the process of bioaccumulation.

4. The levels of methyl-mercury are much higher in marlin than can be explained by the levels in the sea water. Use the food web to explain why.

(Expert) – Explain why it is difficult to predict the impact of population change.

5. Mackerel are fished on a wide scale. Use the food web to explain why it is difficult to predict how this could have an effect on other populations in the community.

STUDENT SHEET 2c: HUMAN IMPACTS SUMMARY (HIGHER)

The food web below shows part of the marine community in the Atlantic Ocean.

Mackerel and marlin are both popular cuisine in the UK, however pregnant women are advised by the NHS not to eat marlin because of the high levels of mercury in their tissues.
Methyl-mercury is a persistent mercury containing chemical in the environment. It occurs naturally, but human activity like mining and burning coal can increase the natural levels on land, in rivers and into the sea.
In humans, mercury poisoning damages the central nervous system causing loss of hearing, speech and vision and ataxia (uncoordinated movements).

(Competent) – Describe the process of bioaccumulation.

1. The relationship between the concentration of mercury in a range of marine organism's tissues and their trophic level is shown in figure 1 below.

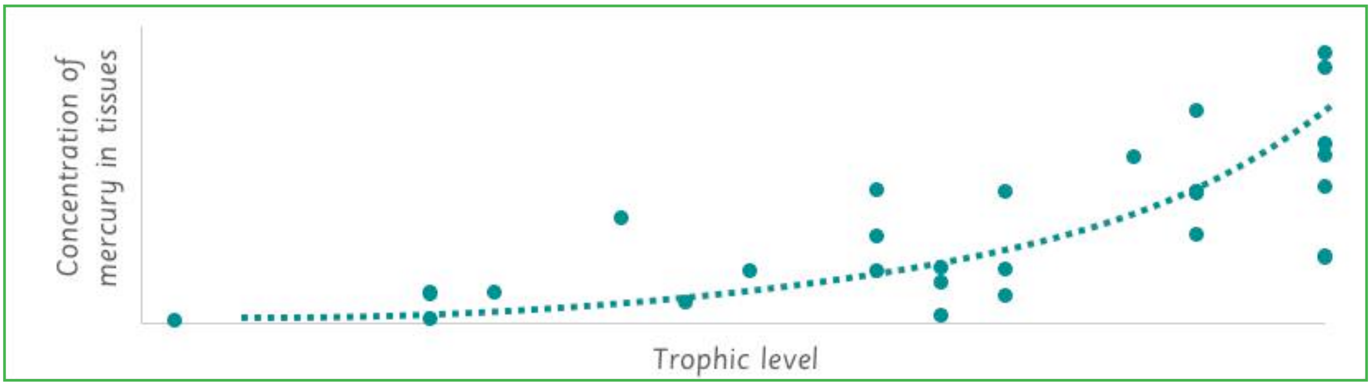


Figure 1: the concentration of mercury in the tissues of marine organisms against their trophic level.

Describe and explain this relationship.

(Expert) – Explain why it is difficult to predict the impact of population change.

2. Mackerel are fished on a wide scale. Use the food web to explain why it is difficult to predict how this could have an effect on other populations in the community.

ANSWER SHEET FOR STUDENT SHEET 2b

<table>
<tr><th colspan="2">Q</th><th>Answer</th><th>Guidance</th></tr>
<tr><td>1</td><td></td><td>Foundation
1. There are many answers to this questions, including, but not limited to:
- Overfishing.
- Releasing chemical waste.
- Releasing harmful chemicals.
- Destroying habitats.
- Oil spills.
- Marine plastics.</td><td>If students have written "pollution" unqualified, encourage them to be more specific about the type of pollution, eg "chemical run-off", "pollution from plastic", "pollution from sewage".</td></tr>
<tr><td>2</td><td></td><td>Developing
1. Methyl-mercury doesn't break down in the environment,
2. for a very long time.</td><td></td></tr>
<tr><td>3</td><td>a</td><td>1. The population could increase.
OR
2. The population could decrease.</td><td></td></tr>
<tr><td></td><td>b</td><td>If the candidate has said "increase" in part (a):
1. There is more food for the squid to eat,
2. because there are fewer mackerel to eat the zooplankton.
OR
If the candidate has said "decrease" in part (a):
1. The marlin have fewer mackerel to eat,
2. so they will eat more squid.</td><td>Explain that the explanation comes in two parts: first students have to say what would happen, then they need to give a reason. These points have to be linked by a connective that shows cause, eg 'because', 'therefore', 'so' etc.</td></tr>
<tr><td>4</td><td></td><td>Competent
Students should explain the process of bioaccumulation:
1. Methyl-mercury is absorbed by phytoplankton,
2. plant plankton are consumed by zooplankton,
3. which passes the methyl-mercury to the zooplankton,
4. the zooplankton eat many phytoplankton, so they get a higher <u>dose</u>,
5. this process is repeated at every trophic level, up to the marlin,
6. this is called bioaccumulation.</td><td>Encourage students to write their answer in a logical order:
bioaccumulation is a prime candidate for long answer questions in exam papers.
'Dose' is preferred to 'more poison' or 'more methyl-mercury'.</td></tr>
<tr><td>5</td><td></td><td>Expert
Students should explain that the complex interrelationships within a community mean it is difficult to make predictions, using specific examples from the food web:
1. There are many relationships or links in a community,
2. the marlin is a predator of both the mackerel and the squid,
3. which are both predators of the zooplankton,
4. the mackerel and squid are competitors,
5. this means fewer mackerel could increase or decrease the populations of all of these organisms,
6. this makes it difficult to predict impact on other populations in the community.</td><td>Students were asked to use the food web so they need to have given examples.</td></tr>
</table>

ANSWER SHEET FOR STUDENT SHEET 2c

Q	Answer	Guidance
1	Competent Students should describe the relationship in the graph: 1. As the trophic level increases, the concentration of mercury in tissues increases, 2. the relationship is not proportional, 3. each increase in trophic level results in a larger increase in concentration. Students should explain the process of bioaccumulation: 1. (Methyl) mercury is absorbed by the organisms at the bottom of the food chain, 2. it moves up the food chains as organisms feed on each other, 3. the dose increases with each trophic level, 4. because each trophic level consumes a larger number of organisms from the level below it, 5. this is called bioaccumulation.	Accept "positive correlation". Encourage students to write their answer in a logical order. 'Dose' is preferred to 'more poison' or 'more methyl-mercury'.
2	Expert Students should explain that the complex interrelationships within a community mean it is difficult to make predictions, using specific examples from the food web: 1. There are many relationships or links in a community, 2. the marlin is a predator of both the mackerel and the squid, 3. which are both predators of the zooplankton, 4. the mackerel and squid are competitors, 5. this means fewer mackerel could increase or decrease the populations of all of these organisms, 6. this makes it difficult to predict impact on other populations in the community.	Students were asked to use the food web so they need to have given examples.

Lesson 3:
What are microplastics and where do they come from?

In this lesson, students develop their understanding of how human actions can have a negative impact on the marine environment.

The context of this lesson is investigating the amount of microplastics that students use every day in personal hygiene products.

Resources in this booklet:

Lesson Overview 3
Teacher Guidance 3

Activity Overview 3 How much microplastic?
Technician Notes 3 How much microplastic?

Student Sheet 3a How much microplastic?
Student Sheet 3b Microplastics summary worksheet
Student Sheet 3c Hunting microplastic home learning

Subject Update 4 Marine plastics
Subject Update 5 Marine plastics facts and figures

Resources available online:

Slideshow 3 available at bit.ly/PPP_SL

LESSON 3: WHAT ARE MICROPLASTICS AND WHERE DO THEY COME FROM?

Lesson overview

In this lesson, students develop their understanding of how human actions can have a negative impact on the marine environment. The context of this lesson is investigating the amount of microplastics that students use every day in personal hygiene products.

Details

Time
60 minutes

Specification links
Waste management & pollution
AQA Trilogy: 4.7 Ecology
AQA Synergy: 4.4 Explaining change
OCR 21: B6 Life on Earth
OCR Gateway: B6 Global challenges
Edexcel: B9 Ecosystems and material cycles

Age
14-16 / GCSE Biology / GCSE Combined Science

Key words

Names	microplastic, personal hygiene product, nurdle, polymer
Processes	life cycle assessment

Lesson steps / Learning outcomes

Step	Lesson steps	Learning outcomes
1 5 mins	**Brief from Dr Matt Cole** Use the slides to set the context and share the learning outcomes.	Understand the wider context and learning outcomes.
2 10 mins	**Where do microplastics come from?** Using the slides, students learn what microplastics are and where they come from. Using the slide-based traffic lights game to assess students' learning.	**Foundation** Say what microplastic is. **Developing** Give sources of microplastics. Define and use the term "microplastic" correctly.
3 25 mins	**Practical work** Students investigate how much microplastic is in different personal hygiene products.	**Competent** Apply your knowledge of concentration, sampling and microplastics. **Expert** Switch between multiples of units and use standard form.
4 15 mins	**Summary assessment worksheet** Students demonstrate their learning by answering questions on Student Sheet 3b.	Demonstrate learning.
5 5 mins	**Self-reflection** Students reflect on their learning by composing a tweet, complete with appropriate hashtags and emojis.	Reflect on learning.

Resources

Activity Overview

Activity Overview 3
How much microplastic?

Technicians Notes

Technician Notes 3
How much microplastic?

Student Sheet

Student Sheet 3a
How much microplastic?

Student Sheet 3b
Microplastics summary worksheet

Student Sheet 3c
Hunting microplastic home learning

Slideshow

Slideshow 3

Subject Updates

Subject Update 4
Marine plastics

Subject Update 5
Marine plastics facts and figures

Differentiation

By task
To support lower ability students, focus on applying knowledge, use questions 4-6 on Student Sheet 3b to assess this.
To challenge higher ability students, focus on using standard form, use question 7 on Student Sheet 3b to assess this.

By support
See the Teacher Guidance for more ideas.

Home learning

Using Student Sheet 3c, students conduct a survey at home to see which of their own personal hygiene products contain microplastic.

Flip it
Ask students complete the hunt prior to the lesson. Use this as a discussion point in Step 1 to illustrate how prolific microplastic use is.

Step

1

5 mins

Contextualising learning:
The purpose of Step 1 is to share the learning outcomes, set the context and engage students with the learning.

Show students the images on **Slides 1-2**. Use the images to draw out ideas that animals can eat plastic or become trapped in it.
Use **Slide 3** to ask students if we should be paying for plastic bags and then use the infographic on **Slide 4** to highlight that five of the top six items found on beaches are made from plastic.

The data on **Slide 4** is from www.oceanconservancy.org who had over half a million volunteers all around the world cleaning up beaches in 2014.

Read the topic brief from Dr Matt Cole on **Slide 5** to put the lesson into context.

This is a good opportunity for students to take the lead and practise reading aloud.

Link this lesson to previous learning using **Slide 6**.

Ask students to write the lesson title from the top left of **Slide 7**, as well as the date and key question into their books. They can then try to guess the missing words from the key question, which in this case are "*microplastic*" and "*where*".

Read the outcomes on **Slide 8** with the students and ask them to put their hands up to show what they can already do.

Challenge students who you think are over or underestimating their current learning by asking targeted questions.

2

10 mins

Developing idea: where do microplastics come from?
The purpose of Step 2 is for students to learn where microplastics come from.

Use **Slides 9-10** to define microplastic and explain where they come from.
Use **Slide 11** to explain that microplastics don't rot because they are synthetic polymers.

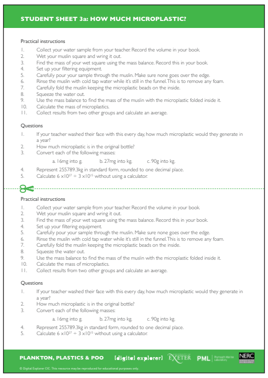
Use the 'Red, Yellow, Green' slides (**Slides 12-22**) and traffic light cards to assess students' understanding of the term 'microplastics'.

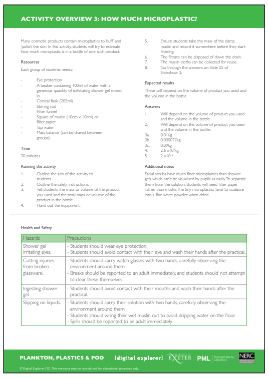
Make a note of students that make significant errors. Resolve their misconceptions during the game and give them spot questions at points through the lesson, to check for learning.

Step

3

25 mins





Developing idea: practical work
The purpose of Step 3 is for students to investigate how much microplastic is in a bottle of a hygiene product.

Hand out **Student Sheet 3a** one between two.
Use **Activity Overview 3** to guide you through the preparation, set up and running of this practical activity.

To support lower ability students allow them to copy the table on **Slide 24**.

This is a standard filtration practical, with students finding the mass of the residue.
Students need to know the volume of product you have 'used' and in the bottle, write on the interactive white board.
See **Technician Notes 3** for detailed preparatory notes.

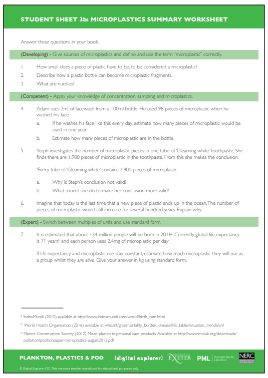
This experiment presents a low risk slipping hazard, a medium risk of injury from broken glassware, low risk hazard from ingesting shower gel and a medium risk to eyes as shower gel can be an irritant.
See **Activity Outline 3** for detailed Health and Safety instructions.

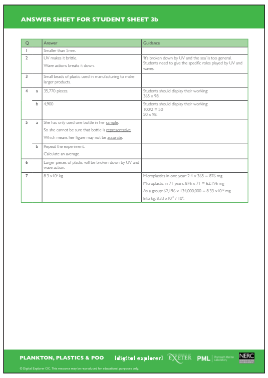
According the Marine Conservation Society UK the actual average use of microplastic is about 2.4 mg of microplastic/person/day.

The answers to the questions are on **Slide 25**. You will need to complete the answers for 1 and 2.

4

15 mins





Demonstrating learning: summary assessment worksheet
The purpose of Step 4 is for students to demonstrate their learning.

Hand out **Student Sheet 3b**. Ask students to complete the questions.
Using the **Answer Sheet**, ask students to peer assess each others' answers.

Ask selected students to read out the comments they have made on their partners' work: this will highlight if they have understood the success criteria.
Poor comments like 'good try' should be replaced using the success criteria and you may have to model this for them.
For home learning, students could improve their answers. To check for progress, peer assess these at the start of another lesson and ask students who has made an improvement.
Highlight that using feedback drives learning.

Step

5

5 mins

Reflecting on learning
The purpose of Step 5 is for students to reflect on their learning.

Ask students to raise their hands to show what outcomes on **Slide 26** they are confident they can do.

Challenge students by asking selected individuals what evidence they have that shows them they can meet an outcome.

Ask students to compose a tweet based on their learning on **Slide 27**. Take feedback from the class.

This activity helps students re-contextualise their learning, by linking it to other areas.

ACTIVITY OVERVIEW 3: HOW MUCH MICROPLASTIC?

Many cosmetic products contain microplastics to 'buff' and 'polish' the skin. In this activity, students will try to estimate how much microplastic is in a bottle of one such product.

Resources

Each group of students needs:

- Eye protection
- A beaker containing 100ml of water with a generous quantity of exfoliating shower gel mixed in
- Conical flask (205ml)
- Stirring rod
- Filter funnel
- Square of muslin (10cm x 10cm) or filter paper
- Tap water
- Mass balance (can be shared between groups)

Time

20 minutes

Running the activity

1. Outline the aim of the activity to students.
2. Outline the safety instructions.
3. Tell students the mass or volume of the product you used and the total mass or volume of the product in the bottle.
4. Hand out the equipment.
5. Ensure students take the mass of the damp muslin and record it somewhere before they start filtering.
6. The filtrate can be disposed of down the drain.
7. The muslin cloths can be collected for reuse.
8. Go through the answers on Slide 25 of Slideshow 3.

Expected results

These will depend on the volume of product you used and the volume in the bottle.

Answers

1. Will depend on the volume of product you used and the volume in the bottle.
2. Will depend on the volume of product you used and the volume in the bottle.

3a. 0.016g.

3b. 0.000027kg.

3c. 0.09kg.

4. 2.6×10^5kg.
5. 2×10^{12}.

Additional notes

Facial scrubs have much finer microplastics than shower gels which can't be visualised by pupils as easily. To separate them from the solution, students will need filter paper rather than muslin. The tiny microplastics tend to coalesce into a fine white powder when dried.

Health and Safety

Hazards	Precautions
Shower gel irritating eyes.	- Students should wear eye protection. - Students should avoid contact with their eye and wash their hands after the practical.
Cutting injuries from broken glassware.	- Students should carry watch glasses with two hands, carefully observing the environment around them. - Breaks should be reported to an adult immediately, and students should not attempt to clear these themselves.
Ingesting shower gel.	- Students should avoid contact with their mouths and wash their hands after the practical.
Slipping on liquids.	- Students should carry their solution with two hands, carefully observing the environment around them. - Students should wring their wet muslin out to avoid dripping water on the floor. - Spills should be reported to an adult immediately.

TECHNICIAN NOTES 3: HOW MUCH MICROPLASTIC?

Many cosmetic products contain microplastics to 'buff' and 'polish' the skin. In this activity, students will try to estimate how much microplastic is in a bottle of one such product.

Resources

Each group of students needs:

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- Conical flask (205ml)
- Stirring rod
- Filter funnel
- Square of muslin (10cm x 10cm) or filter paper
- Tap water
- Mass balance (can be shared between groups)

Time

20 minutes

Running the activity

This is a standard filtration practical, with students finding the mass of the residue.

Additional notes

Which shower gels and facial scrubs should we use?

Cosmetics containing microplastics can be purchased from convenience stores or supermarkets. If you look at the backs of the packaging, products containing plastics will have either polyethylene, polypropylene, copolymer acrylates, or acrylates copolymer listed in the ingredients. If you are unsure, you can download the smartphone app from http://beatthemicrobead.org which allows you to scan product barcodes to find out whether they contain plastic microbeads or not.

Shower gels (additional information)

Microplastics used in shower gels tend to be spherical and brightly coloured, being a decorative addition to many products. Shower gels can also contain much smaller bits of plastic, but these are far more numerous in facial scrubs. Muslin acts as a coarse filter, so will only collect larger bits of plastic. The filtering is generally quick, but students may need to keep rinsing the muslin with cold water to remove any foam.

Facial scrubs (additional information)

Facial scrubs have much finer microplastics which can't be visualised by pupils as easily. To separate them from the solution, students will need filter paper rather than muslin. Depending on the product used, filtering the facial scrub solution can take a couple of minutes. After carefully unfolding their filters, the tiny microplastics tend to coalesce into a fine white layer. If they have time, students can dry their filter papers in a 60°C oven or on a radiator.

Hazards	Precautions
Shower gel irritating eyes.	- Students should wear eye protection. - Students should avoid contact with their eye and wash their hands after the practical.
Cutting injuries from broken glassware.	- Students should carry watch glasses with two hands, carefully observing the environment around them. - Breaks should be reported to an adult immediately, and students should not attempt to clear these themselves.
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Slipping on liquids.	- Students should carry their solution with two hands, carefully observing the environment around them. - Students should wring their wet muslin out to avoid dripping water on the floor. - Spills should be reported to an adult immediately.

University of Exeter | PML Plymouth Marine Laboratory | NERC Science of the Environment | Encounter Edu

STUDENT SHEET 3a: HOW MUCH MICROPLASTIC?

Practical instructions

1. Collect your water sample from your teacher. Record the volume in your book.
2. Wet your muslin square and wring it out.
3. Find the mass of your wet square using the mass balance. Record this in your book.
4. Set up your filtering equipment.
5. Carefully pour your sample through the muslin. Make sure none goes over the edge.
6. Rinse the muslin with cold tap water while it's still in the funnel. This is to remove any foam.
7. Carefully fold the muslin keeping the microplastic beads on the inside.
8. Squeeze the water out.
9. Use the mass balance to find the mass of the muslin with the microplastic folded inside it.
10. Calculate the mass of microplastics.
11. Collect results from two other groups and calculate an average.

Questions

1. If your teacher washed their face with this every day, how much microplastic would they generate in a year?
2. How much microplastic is in the original bottle?
3. Convert each of the following masses:

   a. 16mg into g. b. 27mg into kg. c. 90g into kg.

4. Represent 255789.3kg in standard form, rounded to one decimal place.
5. Calculate $6 \times 10^{27} \div 3 \times 10^{15}$ without using a calculator.

Practical instructions

1. Collect your water sample from your teacher. Record the volume in your book.
2. Wet your muslin square and wring it out.
3. Find the mass of your wet square using the mass balance. Record this in your book.
4. Set up your filtering equipment.
5. Carefully pour your sample through the muslin. Make sure none goes over the edge.
6. Rinse the muslin with cold tap water while it's still in the funnel. This is to remove any foam.
7. Carefully fold the muslin keeping the microplastic beads on the inside.
8. Squeeze the water out.
9. Use the mass balance to find the mass of the muslin with the microplastic folded inside it.
10. Calculate the mass of microplastics.
11. Collect results from two other groups and calculate an average.

Questions

1. If your teacher washed their face with this every day, how much microplastic would they generate in a year?
2. How much microplastic is in the original bottle?
3. Convert each of the following masses:

   a. 16mg into g. b. 27mg into kg. c. 90g into kg.

4. Represent 255789.3kg in standard form, rounded to one decimal place.
5. Calculate $6 \times 10^{27} \div 3 \times 10^{15}$ without using a calculator.

STUDENT SHEET 3b: MICROPLASTICS SUMMARY WORKSHEET

Answer these questions in your book.

(Developing) - Give sources of microplastics and define and use the term "microplastic" correctly.

1. How small does a piece of plastic have to be, to be considered a microplastic?
2. Describe how a plastic bottle can become microplastic fragments.
3. What are nurdles?

(Competent) - Apply your knowledge of concentration, sampling and microplastics.

4. Adam uses 2ml of facewash from a 100ml bottle. He used 98 pieces of microplastic when he washed his face.
    a. If he washes his face like this every day, estimate how many pieces of microplastic would be used in one year.
    b. Estimate how many pieces of microplastic are in the bottle.

5. Steph investigates the number of microplastic pieces in one tube of 'Gleaming white' toothpaste. She finds there are 1,900 pieces of microplastic in the toothpaste. From this she makes the conclusion:

    'Every tube of 'Gleaming white' contains 1,900 pieces of microplastic.'

    a. Why is Steph's conclusion not valid?
    b. What should she do to make her conclusion more valid?

6. Imagine that today is the last time that a new piece of plastic ends up in the ocean. The number of pieces of microplastic would still increase for several hundred years. Explain why.

(Expert) - Switch between multiples of units and use standard form.

7. It is estimated that about 134 million people will be born in 2016[a]. Currently, global life expectancy is 71 years[b] and each person uses 2.4mg of microplastic per day[c].

    If life expectancy and microplastic use stay constant, estimate how much microplastic they will use as a group whilst they are alive. Give your answer in kg using standard form.

---

[a] IndexMundi (2015) available at http://www.indexmundi.com/world/birth_rate.html

[b] World Health Organisation (2016) available at who.int/gho/mortality_burden_disease/life_tables/situation_trends/en/

[c] Marine Conservation Society (2012) Micro plastics in personal care products. Available at http://www.mcsuk.org/downloads/pollution/positionpaper-microplastics-august2012.pdf

STUDENT SHEET 3c: HUNTING MICROPLASTICS HOME LEARNING

Microplastic hunt
Are you using microplastics at home?

Shower gels, facial scrubs and even toothpaste can contain microplastics. When you get home, take a look at the product label to try and identify whether you are washing your face or brushing your teeth with plastic! You can even get a mobile app from www.beatthemicrobead.org that can help you find products that are microplastic free!

Make a list in your book. Highlight anything that surprises you.

How do you know whether you are looking at plastic?

Companies which produce shower gels and facial scrubs have to put all the ingredients on the back of the bottle. Take a look at the label on the back of the products you have just used. Microplastics are most commonly made of 'polyethylene', 'polypropylene', 'copolymer acrylates', or 'acrylates copolymer'.

Microplastic hunt
Are you using microplastics at home?

Shower gels, facial scrubs and even toothpaste can contain microplastics. When you get home, take a look at the product label to try and identify whether you are washing your face or brushing your teeth with plastic! You can even get a mobile app from www.beatthemicrobead.org that can help you find products that are microplastic free!

Make a list in your book. Highlight anything that surprises you.

How do you know whether you are looking at plastic?

Companies which produce shower gels and facial scrubs have to put all the ingredients on the back of the bottle. Take a look at the label on the back of the products you have just used. Microplastics are most commonly made of 'polyethylene', 'polypropylene', 'copolymer acrylates', or 'acrylates copolymer'.

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Make a list in your book. Highlight anything that surprises you.

How do you know whether you are looking at plastic?

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Microplastic hunt
Are you using microplastics at home?

Shower gels, facial scrubs and even toothpaste can contain microplastics. When you get home, take a look at the product label to try and identify whether you are washing your face or brushing your teeth with plastic! You can even get a mobile app from www.beatthemicrobead.org that can help you find products that are microplastic free!

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Companies which produce shower gels and facial scrubs have to put all the ingredients on the back of the bottle. Take a look at the label on the back of the products you have just used. Microplastics are most commonly made of 'polyethylene', 'polypropylene', 'copolymer acrylates', or 'acrylates copolymer'.

ANSWER SHEET FOR STUDENT SHEET 3b

Q		Answer	Guidance
1		Smaller than 5mm.	
2		UV makes it brittle. Wave actions breaks it down.	'It's broken down by UV and the sea' is too general. Students need to give the specific roles played by UV and waves.
3		Small beads of plastic used in manufacturing to make larger products.	
4	a	35,770 pieces.	Students should display their working: 365 × 98.
	b	4,900	Students should display their working: 100/2 = 50 50 × 98.
5	a	She has only used one bottle in her <u>sample</u>. So she cannot be sure that bottle is <u>representative</u>. Which means her figure may not be <u>accurate</u>.	
	b	Repeat the experiment. Calculate an average.	
6		Larger pieces of plastic will be broken down by UV and wave action.	
7		8.3×10^6 kg.	Microplastics in one year: 2.4 × 365 = 876 mg Microplastic in 71 years: 876 × 71 = 62,196 mg As a group: 62,196 × 134,000,000 = 8.33×10^{12} mg Into kg: $8.33 \times 10^{12} / 10^6$.

Lesson 4:
Do zooplankton and microplastics occur together?

In this lesson students learn how to apply sampling techniques, using real field data collected by Dr Lewis' team.

The context of this lesson is the voyage the team took to the Gulf of Maine to investigate if zooplankton and microplastics co-occur.

Resources in this booklet:

- Lesson Overview 4
- Teacher Guidance 4
- Student Sheet 4a Do zooplankton and microplastics occur together?
- Student Sheet 4b Do zooplankton and microplastics occur together? (higher)
- Answer Sheet for Student Sheet 4a and 4b

Resources available online:

- Slideshow 4 available at bit.ly/PPP_SL
- Video 2 Science under sail available at bit.ly/PPP_Vid2

LESSON 4: DO ZOOPLANKTON AND MICROPLASTIC OCCUR TOGETHER?

Lesson overview

In this lesson students learn how to apply sampling techniques, using real field data collected by Dr Lewis' team.

The context of this lesson is the voyage the team took to the Gulf of Maine to investigate if zooplankton and microplastics co-occur.

Details

Time
60 minutes

Specification links
Working scientifically:
- Sampling techniques

Age
14-16 / GCSE Biology / GCSE Combined Science

Key words

Names	population, sample
Processes	trawling
Concepts	accurate, bias, representative

Lesson steps / Learning outcomes

Step	Lesson steps	Learning outcomes
1 (10 mins)	Use the slides to set the context and share the learning outcomes.	Understand the wider context and learning outcomes.
2 (15 mins)	**Sampling** Using slides, students consider different sample sizes to understand the trade-off between being representative and time / cost issues. Using slides, students learn how to estimate from a sample.	**Developing** Use the key words correctly. **Competent** Apply sampling techniques. **Expert** Evaluate sampling techniques.
3 (10 mins)	**Collecting data at sea** Use the video to stimulate a discussion about how and why the team worked to collect their data.	**Foundation** Describe how to collect data at sea. **Competent** Apply sampling techniques.
4 (20 mins)	**Summary assessment worksheet** Students demonstrate their learning by completing the summary worksheet with the real field data collected by Dr Lewis' team in the video.	Demonstrate learning.
5 (5 mins)	**Self-reflection** Using slides, students consider how alternative 'teachers' may have delivered the lesson.	Reflect on learning.

Resources

Student Sheet

Student Sheet 4a
Do zooplankton and microplastics occur together?

Student Sheet 4b
Do zooplankton and microplastics occur together? (higher)

Slideshow

Slideshow 4

Multimedia

Video 2 Science under sail

Answer Sheet

Answer Sheet for Student Sheet 4a and 4b

Home learning

Students improve their answers.

Flip it
Ask students to watch the video prior to the lesson and answer the questions on one of the video worksheets.

Differentiation

By outcome
To support lower ability students, focus on how the scientists have made sure their sample is representative.
To challenge higher ability students, focus on the reasons behind the way the team apply their techniques. This will help them with evaluating.

By support
See the Teacher Guidance for more ideas.

TEACHER GUIDANCE 4: DO ZOOPLANKTON AND MICROPLASTIC OCCUR TOGETHER?

Step

1

10 mins

Contextualising learning: the story so far
The purpose of Step 1 is to share the learning outcomes, set the context and engage students with the learning.

Ask students to write the lesson title from the top left of **Slide 1**, as well as the date and key question into their books. They can then try to guess the missing words from the key question, which in this case are "*occur*" and "*ocean*".

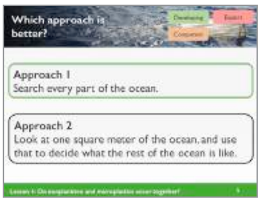
Read the outcomes on **Slide 2** with the students and ask them to put their hands up to show what they can already do.

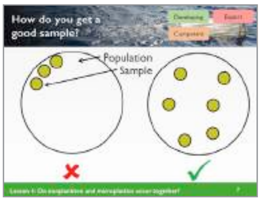
Challenge students who you think are over or underestimating their current learning by asking targeted questions.

Read the story so far on **Slide 3** to put the lesson into context.

2

15 mins





Developing idea: sampling
The purpose of Step 2 is for students to develop their understanding of sampling.

Show students the question on **Slide 4** then the approaches on **Slide 5**. Ask them to discuss in pairs which approach would be better for collecting data.

Approach 1, searching everywhere would be more accurate but ultimately too time consuming to be used.
Approach 2, using a very small sample, would take less time, but would be much less accurate.

Take feedback and use this to explain why in reality we use a combination of the two techniques, which is called sampling.

Use **Slides 6-7** to explain what a representative sample is and how larger and random sampling increase how representative and therefore accurate your sampling is.

Use **Slide 8** to deepen students' ideas about the drawbacks of using large samples.

Highlight specific issues such as the time to collect data and the time to analyse it afterwards, or the costs of equipment, storage and transport.

Ask students targeted questions.
For less able students, focus on how to make the sample representative, with questions like 'How does increasing the sample size affect the accuracy of your estimations?' and 'Why does bias have less of an effect in a large sample?'
For more able students, focus on the need to balance scientific validity with other issues such as cost, with questions like 'To what extent do you agree with the statement: 'the bigger the sample, the better'?

Use the worked example on **Slides 9-13** to show students how to estimate a population from a sample.

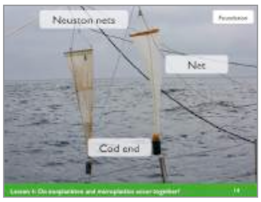
Highlight the tips of interpreting and calculating with standard form.

TEACHER GUIDANCE 4: DO ZOOPLANKTON AND MICROPLASTIC OCCUR TOGETHER?

Step

3

10 mins



Developing idea: collecting data at sea
The purpose of Step 3 is for students to understand how Dr Lewis' team applied sampling techniques to their investigation.

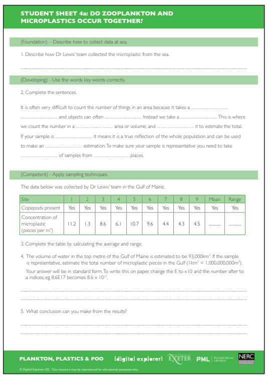
Show students **Video 2** (bit.ly/PPP_Vid2)
Discuss students' initial ideas about how the team have collected their data.

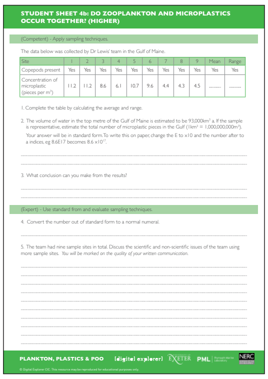
Video 2 can also be set as home learning to watch before the lesson. The two relevant Student Sheets are linked in the video description or can be found in the Video Lessons section of the Resources booklet or as a separate download from bit.ly/PPP_VA. One is a simple recall activity, the other takes a more reflective approach to learning from videos. An Answer Sheet for the recall questions is also included.

Using **Slides 14-20**, show students how the team trawled the ocean for microplastic.

4

20 mins





Demonstrating learning: summary assessment worksheet
The purpose of Step 4 is for students to demonstrate their learning.

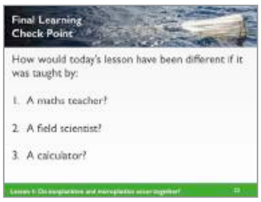
Hand out **Student Sheet 4a** or **4b**. Ask students to complete the questions.
Using the **Answer Sheet**, ask students to peer assess each others' answers.

To support lower ability students, give them a list of key words to include for question 2 of **Student Sheet 4a**.

Ask selected students to read out the comments they have made on their partners' work: this will highlight if they have understood the success criteria.
Poor comments like 'good try' should be replaced using the success criteria and you may have to model this for them.
For home learning, students could improve their answers. To check for progress, peer assess these at the start of another lesson and ask students who has made an improvement.
Highlight that using feedback drives learning.

5

5 mins



Reflecting on learning
The purpose of Step 5 is for students to reflect on their learning.

Ask students to raise their hands to show what outcomes on **Slide 21** they are confident they can do.

Challenge students by asking selected individuals what evidence they have that shows them they can meet an outcome.

Ask students to complete the reflection questions on **Slide 22**. Take feedback from the class.

This activity helps students re-contextualise their learning, by linking it to other areas.

Round off the lesson by reading Dr Matt Cole's final thoughts on **Slide 23**.

STUDENT SHEET 4a: DO ZOOPLANKTON AND MICROPLASTICS OCCUR TOGETHER?

(Foundation) – Describe how to collect data at sea.

1. Describe how Dr Lewis' team collected the microplastic from the sea.

....

(Developing) - Use the words key words correctly.

2. Complete the sentences.

It is often very difficult to count the number of things in an area because it takes a .... and objects can often .... Instead we take a .... This is where we count the number in a .... area or volume, and .... it to estimate the total. If your sample is .... it means it is a true reflection of the whole population and can be used to make an .... estimation. To make sure your sample is representative you need to take .... of samples from ....places.

(Competent) - Apply sampling techniques.

The data below was collected by Dr Lewis' team in the Gulf of Maine.

Site	1	2	3	4	5	6	7	8	9	Mean	Range
Copepods present	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Concentration of microplastic (pieces per m^3)	11.2	1.3	8.6	6.1	10.7	9.6	4.4	4.3	4.5	....	....

3. Complete the table by calculating the average and range.

4. The volume of water in the top metre of the Gulf of Maine is estimated to be $93,000km^3$. If the sample is representative, estimate the total number of microplastic pieces in the Gulf ($1km^3 = 1,000,000,000m^3$).

   Your answer will be in standard form. To write this on paper, change the E to x10 and the number after to a indices, eg 8.6E17 becomes 8.6×10^{17}.

....

....

5. What conclusion can you make from the results?

....

....

STUDENT SHEET 4b: DO ZOOPLANKTON AND MICROPLASTICS OCCUR TOGETHER? (HIGHER)

(Competent) - Apply sampling techniques.

The data below was collected by Dr Lewis' team in the Gulf of Maine.

Site	1	2	3	4	5	6	7	8	9	Mean	Range
Copepods present	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Concentration of microplastic (pieces per m^3)	11.2	11.2	8.6	6.1	10.7	9.6	4.4	4.3	4.5	....	....

1. Complete the table by calculating the average and range.

2. The volume of water in the top metre of the Gulf of Maine is estimated to be 93,000km^3 a. If the sample is representative, estimate the total number of microplastic pieces in the Gulf (1km^3 = 1,000,000,000m^3).

   Your answer will be in standard form. To write this on paper, change the E to x10 and the number after to a indices, eg 8.6E17 becomes 8.6 x10^{17}.

....

....

3. What conclusion can you make from the results?

....

....

(Expert) - Use standard from and evaluate sampling techniques.

4. Convert the number out of standard form to a normal numeral.

....

5. The team had nine sample sites in total. Discuss the scientific and non-scientific issues of the team using more sample sites. *You will be marked on the quality of your written communication.*

....

....

....

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....

ANSWER SHEET FOR STUDENT SHEETS 4a AND 4b

Student Sheet 4a

Q	Answer	Guidance
1	They trawled using a neuston net.	
2	It is often very difficult to count the number of things in an area because it takes a **long time** and objects can often **move**. Instead we take a **sample**. This is where we count the number in a **small / set** area or volume, and **multiply** it to estimate the total. If your sample is **representative** it means it is a true reflection of the whole population and can be used to make an **accurate** estimation. To make sure your sample is representative you need to take **a lot** of samples from **random / a range of** places.	
3	Mean = 6.7 Range = 9.9	
4	6.231×10^{14}	Students should show their working: 6.7 × 93,000 × 10,000,000,000 Accept follow through errors from question 3.
5	Microplastics and zooplankton occur together.	

Student Sheet 4b

<table>
<tr><th>Q</th><th colspan="2">Answer</th><th colspan="2">Guidance</th></tr>
<tr><td>1</td><td colspan="2">A samples that is the true reflection of the whole population.</td><td colspan="2"></td></tr>
<tr><td>2</td><td colspan="2">Mean = 6.7
Range = 9.9</td><td colspan="2"></td></tr>
<tr><td>3</td><td colspan="2">6.231×10^{14}</td><td colspan="2">Students should show their working:
6.7 93,000 × 1,000,000,000
Accept follow through errors from question 3.</td></tr>
<tr><td>4</td><td colspan="2">623,100,000,000,000</td><td colspan="2"></td></tr>
<tr><td rowspan="4">5</td><th>Level</th><th>Literacy</th><th>Content</th><th>Points</th></tr>
<tr><td>1</td><td>- Many spelling errors.
- Full stops and capitals rarely used correctly.
- Answer is not well organised.
- Some science vocab.</td><td>Gives TWO or more issues from any area.</td><td rowspan="3">Scientific issue
More sites:
- Make sample more representative.
- Less effected by bias.
More representative samples:
- Truer reflection of population.
- Allow more accurate estimation.
Non-scientific issues
Time implications:
- Time to collect.
- Time to analyse.
Cost implications:
- Cost of collecting the samples, eg paying people, renting boat / equipment.
- Cost of storing samples.
- Cost of transporting samples.</td></tr>
<tr><td>2</td><td>- Some spelling errors.
- Full stops and capitals used correctly.
- Answer covers most of the major points, but may not be logically organised.
- Good use of science vocab.</td><td>Fully explains ONE issue
OR
partially explains a scientific and a non-scientific issue.</td></tr>
<tr><td>3</td><td>- Few spelling errors.
- Good use of punctuation.
- If a diagram is used, presented clearly.
- Large variety of science vocab used.
- Answer divided into sensible paragraphs.
- Answer flows in a logical order.</td><td>Fully explains BOTH a scientific and non-scientific issue.</td></tr>
<tr><td>6</td><td colspan="2">Microplastics and zooplankton occur together.</td><td colspan="2"></td></tr>
</table>

Lesson 5:
Do zooplankton eat microplastics?
(Experiment set-up and data handling)

This lesson develops students' skills in data handling and presentation.

Having learnt about microplastics and zooplankton separately, the next two lessons see students test the hypothesis that zooplankton eat microplastics. In this first lesson, students set up a classroom practical to collect primary data. They then process the secondary data collected by Dr Ceri Lewis and her team.

In the next lesson, students will practise drawing conclusions from their own observations and Dr Lewis' data.

Resources in this booklet:

Lesson Overview 5
Teacher Guidance 5

Activity Overview 5 Do zooplankton eat microplastics?
Technician Notes 5 Do zooplankton eat microplastics?

Student Sheet 5a Do zooplankton eat microplastics? (Practical)
Student Sheet 5b Do zooplankton eat microplastics? (Data analysis)

Answer Sheet 5b

Resources available online:

Slideshow 5 available at bit.ly/PPP_SL

Video 3 Science in the lab available at bit.ly/PPP_Vid3

LESSON 5: DO ZOOPLANKTON EAT MICROPLASTICS? EXPERIMENT SET-UP AND DATA HANDLING

Lesson overview

This lesson develops students' skills in data handling and presentation.

Having learnt about microplastics and zooplankton separately, the next two lessons sees students test the hypothesis that zooplankton eat microplastics. In this first lesson, students set up a classroom practical to collect primary data. They then process the secondary data collected by Dr Ceri Lewis and her team.

In the next lesson, students will practise drawing conclusions from their own observations and Dr Lewis' data.

Details

Time
60 minutes

Specification links
Working scientifically
- Mathematical & statistical analysis
- Presenting & transforming data

Age
14-16 / GCSE Biology / GCSE Combined Science

Key words

Names	average, line of best fit, range, range bar
Concepts	even scale, units

Lesson steps

Step	Lesson steps	Learning outcomes
1 (15 mins)	**Brief from Dr Matt Cole** Use the slides to set the context and share the learning outcomes. Use the video to discuss the wider context and introduce some of the lesson's ideas.	Understand the wider context and the learning outcomes.
2 (10 mins)	**Common mistakes in graphs** Using the slides, students learn common mistakes that are made when people draw graphs.	**Competent** Draw lines of best fit, and range bars.
3 (10 mins)	**Practical set-up** Students set up their practical to investigate if zooplankton eat microplastic. Students will study the results of their experiments in the next lesson.	Set up the practical investigation safely.
4 (20 mins)	**Handling and presenting field data** Students practise their data handling and data presentation skills using the real data collected by Dr Lewis' team in the field.	**Developing** Calculate averages, choose appropriate graphs and scales. **Competent** Handle anomalies, draw lines of best fit, and range bars.
5 (5 mins)	**Self-reflection** Using slides, students consider how alternative 'teachers' may have delivered the lesson.	Reflect on learning.

Resources

Activity Overview

Activity Overview 5
Do zooplankton eat microplastics?

Technician Notes

Technician Notes 5
Do zooplankton eat microplastics?

Student Sheet

Student Sheet 5a
Do zooplankton eat microplastics? (Practical)

Student Sheet 5b
Do zooplankton eat microplastics? (Data analysis)

Slideshow

Slideshow 5

Multimedia

Video 3 Science in the lab

Answer Sheet

Answer Sheet 5b

Differentiation

By outcome
The open summary assessment task allow students to demonstrate their learning at any level.

By support
See the Teacher Guidance for more ideas.

Home learning

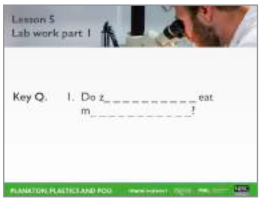
Students improve their graphs or calculations.

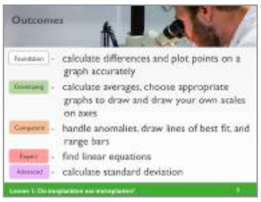
Flip it
Ask students to watch the video prior to the lesson and answer the questions on one of the video worksheets.

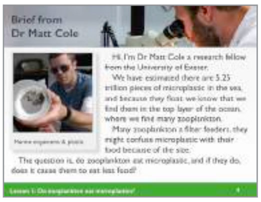
Step

1

15 mins







Contextualising learning
The purpose of Step 1 is to share the learning outcomes, set the context and engage students with the learning.

Ask students to write the lesson title from the top left of **Slide 1** as well as the date and key question into their books. They can then try to guess the missing words from the key question, which in this case are "*zooplankton*" and "*microplastic*".

Read the outcomes on **Slide 2** with the students and ask them to put their hands up to show what they can already do.
Link this lesson to previous learning using **Slide 3**.

Challenge students who you think are over or underestimating their current learning by asking targeted questions.

Read the topic brief from Dr Matt Cole on **Slide 4** put the lesson into context.

This is a good opportunity for students to take the lead and practise reading aloud.

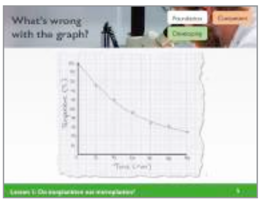
Show students **Video 3**. This reminds students of the hypothesis and introduces students to the feeding experiments Dr Lewis' team conducted in the lab at Exeter University.

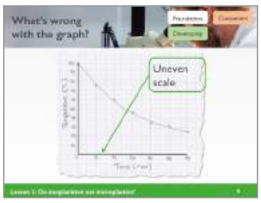
Ask students to summarise the video in 10 words or less and take some examples from the class.

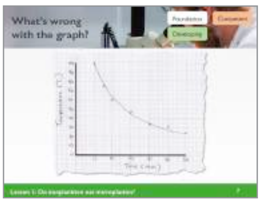
Video 3 can also be set as home learning to watch before the lesson. The two relevant Student Sheets are linked in the video description or can be found in the Video Lessons section of the Resources booklet. One is a simple recall activity, the other takes a more reflective approach to learning from videos. An Answer Sheet for the recall questions is also included.

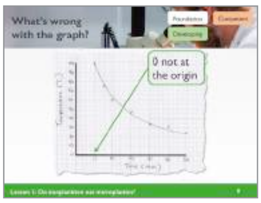
2

10 mins









Developing idea: common graph mistakes
The purpose of Step 2 is for students to refresh their graph drawing skills.

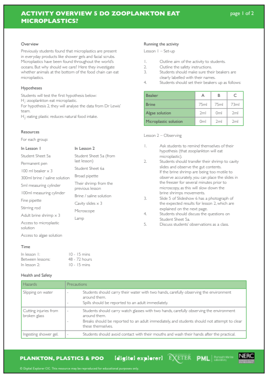
Show students the graph on **Slide 5**. Ask them to spot the mistake by discussing the graph in pairs.
Use **Slide 6** to highlight the error. Explain to students how to correct the error.
Repeat this with **Slides 7-8**, **9-10** and **11-12**.

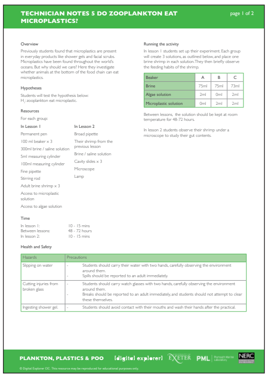
Slides 5-6 show a graph with an uneven scale on the x-axis.
Slides 7-8 show a graph where the origin isn't on the y-axis.
Slides 9-10 show a graph without units.
Slides 11-12 show a graph with a line drawn incorrectly.

Step

3

10 mins


ACTIVITY OVERVIEW 5 DO ZOOPLANKTON EAT MICROPLASTICS?


TECHNICIAN NOTES 5 DO ZOOPLANKTON EAT MICROPLASTICS?

Developing idea: practical work
The purpose of Step 3 is for students to set up their practical so they can collect primary data about zooplankton feeding on microplastics.

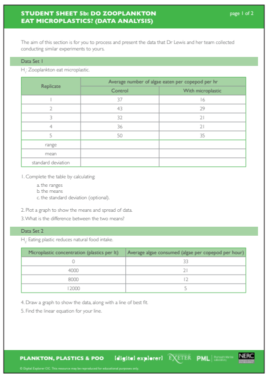
Use **Activity Overview 5** Do zooplankton eat microplastics? to guide you through the preparation, set up and running of this practical activity.

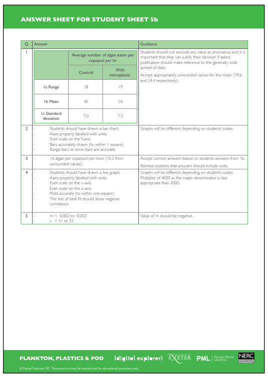
The brine shrimp and solutions of algae and microplastic need advanced preparation.
Once set up, the experiment needs to be left for 48-72 hours to allow the shrimp time to feed.
See **Technician Notes 5** for detailed preparatory notes.

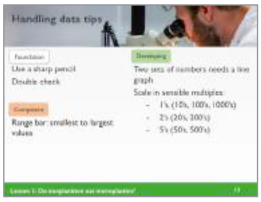
This experiment presents medium risk hazards cuts from broken glass and low risk hazards of slipping and ingesting shower gel.
See **Activity Outline 5** for detailed Health and Safety instructions.

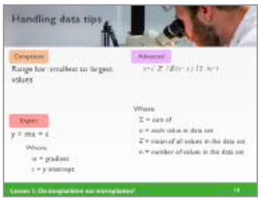
4

20 mins


STUDENT SHEET 5b: DO ZOOPLANKTON EAT MICROPLASTICS? (DATA ANALYSIS)


ANSWER SHEET FOR STUDENT SHEET 5b





Demonstrating learning: handling and presenting field data
The purpose of Step 4 is for students to practise their data handling and presentation skills using the real data collected by Dr Lewis' team in the lab.

Hand out **Student Sheet 5b.** Ask students to work through the questions to process and present the data from two experiments conducted by Dr Lewis' team.
Display either **Slide 13 or 14** on the board to give students additional support.

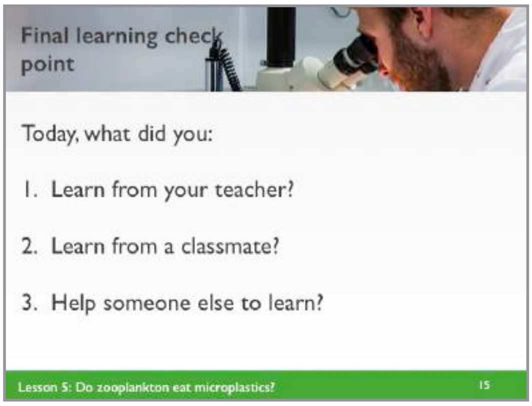
In the next lesson, they will be using this data and data from their own experiments to make conclusions.

Display **Answer Sheet 5b** on the board. Ask students to use this to complete the peer assessment section on **Student Sheet 5b.**

Students should highlight the statements in the peer assessment grid to indicate what has been achieved, and then write a target in the target box.

5

5 mins



Reflecting on learning
The purpose of Step 5 is for students to reflect on their learning and place it back into context.

Final learning check point (Assessment for Learning).

Ask students to complete the reflection questions on **Slide 15.** Take feedback from the class.

ACTIVITY OVERVIEW 5 DO ZOOPLANKTON EAT MICROPLASTICS?

Overview

Previously students found that microplastics are present in everyday products like shower gels and facial scrubs. Microplastics have been found throughout the world's oceans. But why should we care? Here they investigate whether animals at the bottom of the food chain can eat microplastics.

Hypotheses

Students will test the first hypothesis below:
H_1: zooplankton eat microplastic.
For hypothesis 2, they will analyse the data from Dr Lewis' team.
H_2: eating plastic reduces natural food intake.

Resources

For each group:

In Lesson 1

Student Sheet 5a

Permanent pen

100 ml beaker x 3

300ml brine / saline solution

5ml measuring cylinder

100ml measuring cylinder

Fine pipette

Stirring rod

Adult brine shrimp x 3

Access to microplastic solution

Access to algae solution

In Lesson 2

Student Sheet 5a (from last lesson)

Student Sheet 6a

Broad pipette

Their shrimp from the previous lesson

Brine / saline solution

Cavity slides x 3

Microscope

Lamp

Time

In lesson 1:	10 - 15 mins
Between lessons:	48 - 72 hours
In lesson 2:	10 - 15 mins

Running the activity

Lesson 1 – Set-up

1. Outline aim of the activity to students.
2. Outline the safety instructions.
3. Students should make sure their beakers are clearly labelled with their names.
4. Students should set their beakers up as follows:

Beaker	A	B	C
Brine	75ml	75ml	73ml
Algae solution	2ml	0ml	2ml
Microplastic solution	0ml	2ml	2ml

Lesson 2 – Observing

1. Ask students to remind themselves of their hypothesis (that zooplankton will eat microplastic).
2. Students should transfer their shrimp to cavity slides and observe the gut contents.
   If the brine shrimp are being too motile to observe accurately, you can place the slides in the freezer for several minutes prior to microscopy, as this will slow down the brine shrimps movements.
3. Slide 5 of Slideshow 6 has a photograph of the expected results for lesson 2, which are explained on the next page.
4. Students should discuss the questions on Student Sheet 5a.
5. Discuss students' observations as a class.

Health and Safety

Hazards	Precautions
Slipping on water	- Students should carry their water with two hands, carefully observing the environment around them. - Spills should be reported to an adult immediately.
Cutting injuries from broken glass	- Students should carry watch glasses with two hands, carefully observing the environment around them. - Breaks should be reported to an adult immediately, and students should not attempt to clear these themselves.
Ingesting shower gel.	- Students should avoid contact with their mouths and wash their hands after the practical.

Expected results

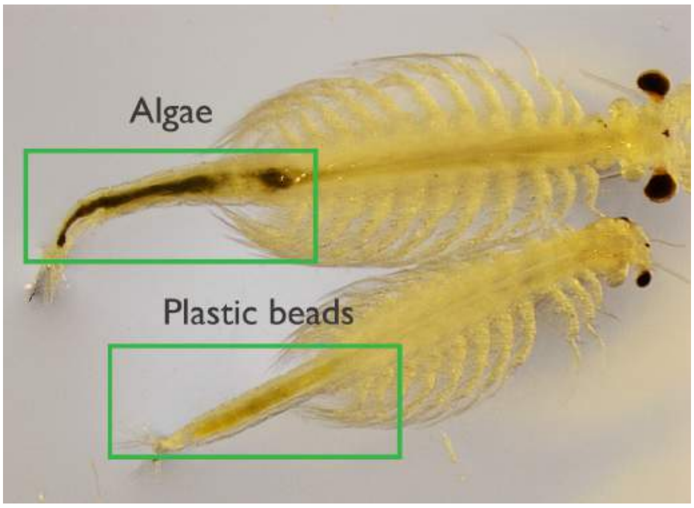
In lesson 1

Brine shrimp are filter-feeders, and will often feed upside down at the water surface. In the oceans, most plastic litter tends to float, so it can be worth pointing out to the students that this feeding behaviour in the wild could mean these animals end up targeting microplastics. Don't expect much of a change in their behaviour after adding microplastics, as they are quite indiscriminate feeders.

In lesson 2

Like most zooplankton, brine shrimp are filter-feeders. The experiment should establish filter feeding as indiscriminate, with these animals having very limited abilities to distinguish between food and plastic.

- In beaker A (algae only), the guts will be full of algae, which should appear green (or green-brown) in colour, and smooth of texture; students may notice algae near the anus are lighter in colour as these are partially digested.
- In beaker B (microplastic only), the guts will be full of plastic, which will appear whitish in colour and may appear "lumpy" and more consistent in colour (as they cannot be digested).
- In beaker C (algae and microplastics), the brine shrimp should have eaten both plastic and algae.



The gut contents of brine shrimp in different environments.

TECHNICIAN NOTES 5 DO ZOOPLANKTON EAT MICROPLASTICS?

Overview

Previously students found that microplastics are present in everyday products like shower gels and facial scrubs. Microplastics have been found throughout the world's oceans. But why should we care? Here they investigate whether animals at the bottom of the food chain can eat microplastics.

Hypotheses

Students will test the hypothesis below:
H_1: zooplankton eat microplastic.

Resources

For each group:

In Lesson 1

Permanent pen

100 ml beaker x 3

300ml brine / saline solution

5ml measuring cylinder

100ml measuring cylinder

Fine pipette

Stirring rod

Adult brine shrimp x 3

Access to microplastic solution

Access to algae solution

In Lesson 2

Broad pipette

Their shrimp from the previous lesson

Brine / saline solution

Cavity slides x 3

Microscope

Lamp

Time

In lesson 1:	10 - 15 mins
Between lessons:	48 - 72 hours
In lesson 2:	10 - 15 mins

Health and Safety

Hazards	Precautions
Slipping on water	- Students should carry their water with two hands, carefully observing the environment around them. - Spills should be reported to an adult immediately.
Cutting injuries from broken glass	- Students should carry watch glasses with two hands, carefully observing the environment around them. - Breaks should be reported to an adult immediately, and students should not attempt to clear these themselves.
Ingesting shower gel.	- Students should avoid contact with their mouths and wash their hands after the practical.

Running the activity

In lesson 1 students set up their experiment. Each group will create 3 solutions, as outlined below, and place one brine shrimp in each solution. They then briefly observe the feeding habits of the shrimp.

Beaker	A	B	C
Brine	75ml	75ml	73ml
Algae solution	2ml	0ml	2ml
Microplastic solution	0ml	2ml	2ml

Between lessons, the solution should be kept at room temperature for 48-72 hours.

In lesson 2 students observe their shrimp under a microscope to study their gut contents.

TECHNICIAN NOTES 5 DO ZOOPLANKTON EAT MICROPLASTICS?

Additional preparation notes

Brine shrimp cultures

Brine shrimp (Artemia) are readily cultured in the laboratory, for which guidelines are readily available online. In summary: mix marine salt (3.5g salt to 100 ml water) with freshwater (note: if tap water leave for a few days to get rid of chlorine), enough to ¾ fill a tank. Add artificial light (but avoid direct sunlight), and leave at room temperature for a couple of days to stabilise. Add a pinch of decapsulated brine shrimp eggs, which can be purchased from pet shops, aquaria or online. Eggs should hatch within 24-48 hours, and as juveniles will gravitate towards the light. Add 5 drops of Liquifry marine (or other filter feed liquid food) to 20 ml water, mix and then add several drops of this food stock to the tank daily. Increase food dosage as brine shrimp grow bigger. Brine shrimp should reach adulthood (<1 cm in length) after 2-3 weeks. At this stage there should be sufficient algal growth in the water (green film on the gravel), and there will be no need to add extra food. Tanks should now be self-sustaining and adults can be collected for experiments.

Microplastic solution

Consists of 10 g of facial scrub (containing microplastics) thoroughly mixed in 100 ml saline water. Any foam can be scooped from the water surface using a spatula. The solution should consist of a suspension of very small white particles.

Johnson & Johnson's Clean and Clear facial scrub has been used successfully. Other brands should be adequate.

Algae solution

The phytoplankton food source for the shrimp will be algae. The solution consists of several drops of algae thoroughly mixed in 100 ml saline water. The solution should be an intense green (or green-brown) colour. Algae suitable for feeding brine shrimp includes live or instant/concentrated: Tetraselmis (green algae), Isochrysis (brown algae) or Dunaliella (green-brown algae).

Algae can be purchased online, try:

www.zmsystems.co.uk or www.blades-bio.co.uk

Broad pipette

We recommend using plastic pipettes with the tapered ends cut off.

Expected results

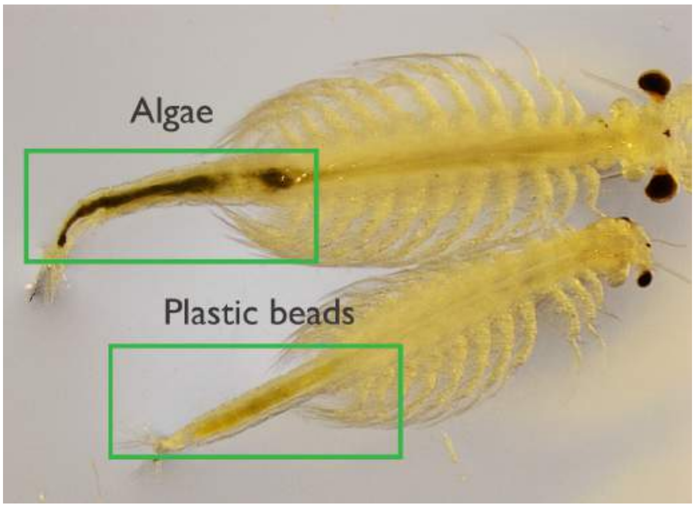
In lesson 1

Brine shrimp are filter-feeders, and will often feed upside down at the water surface. In the oceans, most plastic litter tends to float, so it can be worth pointing out to the students that this feeding behaviour in the wild could mean these animals end up targeting microplastics. Don't expect much of a change in their behaviour after adding microplastics, as they are quite indiscriminate feeders.

In lesson 2

Like most zooplankton, brine shrimp are filter-feeders. The experiment should establish filter feeding as indiscriminate, with these animals having very limited abilities to distinguish between food and plastic.

- In beaker A (algae only), the guts will be full of algae, which should appear green (or green-brown) in colour, and smooth of texture; students may notice algae near the anus are lighter in colour as these are partially digested.
- In beaker B (microplastic only), the guts will be full of plastic, which will appear whitish in colour and may appear "lumpy" and more consistent in colour (as they cannot be digested).
- In beaker C (algae and microplastics), the brine shrimp should have eaten both plastic and algae.



The gut contents of brine shrimp in different environments.

STUDENT SHEET 5a: DO ZOOPLANKTON EAT MICROPLASTICS? (PRACTICAL)

Overview

Previously we found that microplastics are present in everyday products like shower gels and facial scrubs. Microplastics have been found throughout the world's oceans. But why should we care?

Brine shrimp are a type of zooplankton that live in brackish waters all around the world. Like many other types of zooplankton, brine shrimp are filter-feeders which graze on phytoplankton, like algae, living in the water. Scientists in Dr Lewis' team are concerned that filter-feeding zooplankton might accidentally feed on microplastics because they can't tell the difference between it and the algae they normally eat. Here you will test whether brine shrimp can eat microplastics or not.

Hypotheses

Remember, Dr Lewis' team have two hypotheses:

Hypothesis 1: Zooplankton eat microplastic.

Hypothesis 2: Eating plastic reduces natural food intake.

Apparatus

Lesson 1

Student Sheet 5a

Permanent pen

100ml beaker x 3

5ml measuring cylinder

100ml measuring cylinder

Fine pipette

Stirring rod

300ml brine / saline solution

Adult brine shrimp x 3

Access to algae solution

Lesson 2

Student Sheet 5a

Student Sheet 6a

Broad pipette

Brine / saline solution

Cavity slides x 3

Microscope

Lamp

Your shrimp from last lesson

Lesson 1

1. Record the hypotheses in your book.
2. Use the marker pen to label one beaker with 'A', one with 'B' and one with 'C'. Add your names as well.
3. Make the solutions up as follows:

Beaker	A	B	C
Brine	75ml	75ml	73ml
Algae solution	2ml	0ml	2ml
Microplastic solution	0ml	2ml	2ml

4. Stir the solutions well, **remember to rinse the stirring rod in-between stirring each beaker.**
5. Use the broad pipette to carefully transfer ONE adult brine shrimp to each beaker.
6. Watch the shrimp: does their feeding behaviour differ between beakers?

Lesson 2

1. Use the broad pipette to remove the brine shrimp from each beaker. Place each brine shrimp on a glass slide in a small drop of saline water.
2. Use a microscope, with a bright external lamp, to look at the gut contents of the brine shrimp. The gut (intestinal tract) runs in a straight line from the mouth to the anus (see the image on the slide). The gut contents are most obvious near the rear of the animal.

Do not use the sun as your light source as this can severely damage your sight.

3. Record the colour and texture of the gut contents for each brine shrimp in the table on Student Sheet 6a. How does this vary between each beaker?
4. Does this experiment support Hypothesis 1?
5. Does this experiment support Hypothesis 2?

STUDENT SHEET 5b: DO ZOOPLANKTON EAT MICROPLASTICS? (DATA ANALYSIS)

The aim of this section is for you to process and present the data that Dr Lewis and her team collected conducting similar experiments to yours.

Data Set 1

H_1: Zooplankton eat microplastic.

Replicate	Average number of algae eaten per copepod per hr	
	Control	With microplastic
1	37	16
2	43	29
3	32	21
4	36	21
5	50	35
range		
mean		
standard deviation		

1. Complete the table by calculating:

   a. the ranges
   b. the means
   c. the standard deviation (optional).

2. Plot a graph to show the means and spread of data.
3. What is the difference between the two means?

Data Set 2

H_2: Eating plastic reduces natural food intake.

Microplastic concentration (plastics per lt)	Average algae consumed (algae per copepod per hour)
0	33
4000	21
8000	12
12000	5

4. Draw a graph to show the data, along with a line of best fit.
5. Find the linear equation for your line.

STUDENT SHEET 5b: DO ZOOPLANKTON EAT MICROPLASTICS? (DATA ANALYSIS)

Peer assessment

1. Shade the grid to show what the person has achieved.
2. Fill a target into the box.

	Foundation	Developing	Competent	Expert	Advanced
Processing data	- Calculated the difference between the two means for Data Set 1.	- Calculated the averages for Data Set 1.	- Handled anomalies when calculating averages.	- Found the linear equation for Data Set 2.	- Calculated the Standard Deviation for Data Set 1.
	Target:				

	Foundation	Developing	Competent	Expert	Advanced
Presenting data	- Plotted points accurately. - Used a pencil and a ruler.	- Drew the correct graphs for both sets of data. - Drew axes with even scales.	- Drew range bars for Data Set 1. - Draw a line of best fit for Data Set 2.	N/A	N/A
	Target:				

ANSWER SHEET FOR STUDENT SHEET 5b

<table>
<tr><th>Q</th><th>Answer</th><th>Guidance</th></tr>
<tr><td>1</td><td>
<table>
<tr><th></th><th colspan="2">Average number of algae eaten per copepod per hr</th></tr>
<tr><th></th><th>Control</th><th>With microplastic</th></tr>
<tr><td>1a Range</td><td>18</td><td>19</td></tr>
<tr><td>1b Mean</td><td>40</td><td>24</td></tr>
<tr><td>1c Standard deviation</td><td>7.0</td><td>7.5</td></tr>
</table>
</td><td>Students should not exclude any value as anomalous and it is important that they can justify their decision if asked. Justification should make reference to the generally wide spread of data.

Accept appropriately unrounded values for the mean (39.6 and 24.4 respectively).</td></tr>
<tr><td>2</td><td>- Students should have drawn a bar chart.
- Axes properly labelled with units.
- Even scale on the Y-axis.
- Bars accurately drawn (to within 1 square).
- Range bars or error bars are accurate.</td><td>Graphs will be different depending on students' scales.</td></tr>
<tr><td>3</td><td>- 16 algae per copepod per hour (15.2 from unrounded values).</td><td>Accept correct answers based on students answers from 1b.

Remind students that answers should include units.</td></tr>
<tr><td>4</td><td>- Students should have drawn a line graph.
- Axes properly labelled with units.
- Even scale on the y-axis.
- Even scale on the x-axis.
- Plots accurate (to within one square).
- The line of best fit should show negative correlation.</td><td>Graphs will be different depending on student's scales. Multiples of 4000 as the major denominator is less appropriate than 2000.</td></tr>
<tr><td>5</td><td>- m = -0.002 to -0.003
- c = 31 to 33</td><td>Value of m should be negative.</td></tr>
</table>

Lesson 6:
Do zooplankton eat microplastics?
(Drawing conclusions)

In this lesson, students return to their experiments from Lesson 5, and observe the gut contents of the brine shrimp, applying model conclusions to what they can see. Students develop their ability to write scientific conclusions using the secondary data from the research team. The lesson ends with students considering the implications of microplastics being consumed by zooplankton on a wide scale.

Resources in this booklet:

Lesson Overview 6
Teacher Guidance 6

Activity Overview 5 Do zooplankton eat microplastics?
Technician Notes 5 Do zooplankton eat microplastics?

Student Sheet 5a Do zooplankton eat microplastics? (Practical)
Student Sheet 6a Model conclusions
Student Sheet 6b Do zooplankton eat microplastics? (Conclusions)

Answer Sheet for Student Sheet 6b

Resources available online:

Slideshow 6 available at bit.ly/PPP_SL

Video 1 Investigating the impact of microplastics available at bit.ly/PPP_Vid1

LESSON 6: DO ZOOPLANKTON EAT MICROPLASTICS? (DRAWING CONCLUSIONS)

Lesson overview

In this lesson, students return to their experiments from Lesson 5, and observe the gut contents of the brine shrimp, applying model conclusions to what they can see. Students develop their ability to write scientific conclusions using the secondary data from the research team.The lesson ends with students considering the implications of microplastics being consumed by zooplankton on a wide scale.

Details

Time
60 minutes

Specification links
Working scientifically
- Interpreting & concluding

Age
14-16 / GCSE Biology / GCSE Combined Science

Key words

Names	conclusion, numerical value, pattern
Concepts	limitation, wider implication

Lesson steps / Learning outcomes

Lesson steps	Learning outcomes
1 (10 mins) **The story so far…** Use the slides to connect this lesson to the previous lesson's learning, examining the hypothesis that zooplankton eat microplastics.	Understand the wider context and the learning outcomes.
2 (10 mins) **Practical work** In small groups, students complete the investigations they set-up last lesson. They examine the gut contents of the brine shrimp to see if zooplankton eat microplastics.	Make observations.
3 (15 mins) **Model conclusions** Using the model conclusions about their brine shrimp experiment on Student Sheet 6a, students develop their ability to write scientific conclusions. Using the slides, students develop a mnemonic to help them remember the structure of a good scientific conclusion.	**Developing** Use results to support conclusions. **Competent** Explain patterns and conclusions wider impacts. **Expert** Describe the limitations of conclusions.
4 (20 mins) **Writing conclusions** Students demonstrate their learning by writing conclusions based on the graphs they created in the previous lesson.	Demonstrate learning.
5 (5 mins) **Self-reflection** Using slides, students consider how alternative 'teachers' may have delivered the lesson.	Reflect on learning.

Resources

Activity Overview
Activity Overview 5
Do zooplankton eat microplastics?

Technician Notes
Technician Notes 5
Do zooplankton eat microplastics?

Student Sheet
Student Sheet 5a
Do zooplankton eat microplastics? (Practical)

Student Sheet 6a
Model conclusions

Student Sheet 6b
Do zooplankton eat microplastics? (Conclusions)

Slideshow
Slideshow 6

Multimedia
Video I Investigating the impact of microplastics

Answer Sheet
Answer Sheet for Student Sheet 6b

Differentiation

By outcome
The open summary assessment task allow students to demonstrate their learning at any level.

By support
See the Teacher Guidance for more ideas.

Home learning

Students improve their conclusions

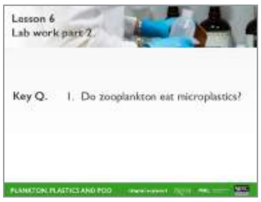
Flip it
Ask students to watch the video prior to the lesson and answer the question 'if your brine shrimp eat microplastics, what effect could this have in the food web and carbon cycle?'.

TEACHER GUIDANCE 6: DO ZOOPLANKTON EAT MICROPLASTICS? (DRAWING CONCLUSIONS)

Step

1

10 mins



Contextualising learning
The purpose of Step 1 is to share the learning outcomes, set the context and engage students with the learning.

Ask students to write the lesson title from the top left of **Slide 1** as well as the date into their books.

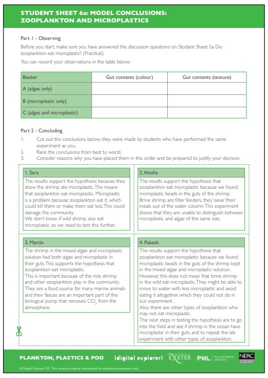
Read the outcomes on **Slide 2** with the students and ask them to put their hands up to show what they can already do.

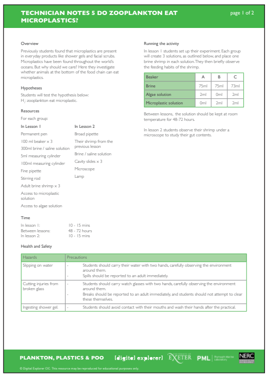
Link this lesson to previous learning using **Slides 3-5**.

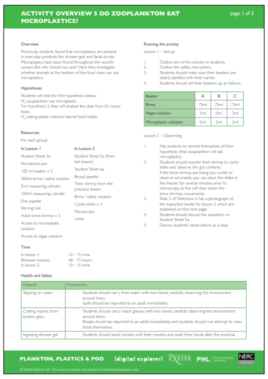
Challenge students who you think are over or underestimating their current learning by asking targeted questions.

2

10 mins







Developing ideas: practical work
The purpose of Step 2 is for students to make observations of zooplankton feeding habits from the practical they set up in the last lesson.

Make sure students still have their copy of **Student Sheet 5a** from yesterday. Hand out **Student Sheet 6a** as well.

Use **Activity Overview 5** to guide you through the preparation, set up and running of this practical activity.

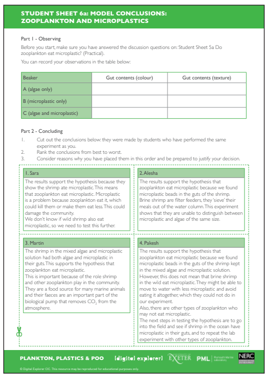
Student Sheet 5a has thinking questions to stimulate discussion. **Student Sheet 6a** has a table for students to record their results and model conclusions which will be used in the next activity.

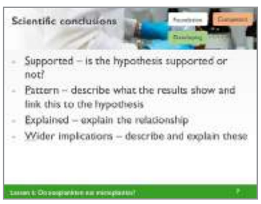
This experiment presents medium risk hazards cuts from broken glass and low risk hazards of slipping and ingesting shower gel.

See **Activity Overview 5** for detailed Health and Safety instructions.

3

15 mins





Developing ideas: model conclusions
The purpose of Step 3 is for students to develop their ability to write conclusions by deconstructing model answers and creating a mnemonic to help them remember the structure of a conclusion.

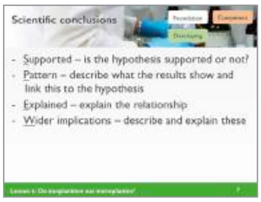
Use **Slide 6** to gather students ideas of what a scientific conclusion should contain.

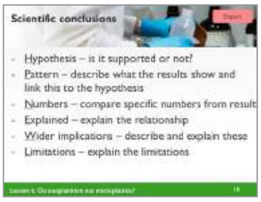
Students should still have a copy of **Student Sheet 6a** from Step 2 which has model conclusions for the experiment students have just completed. Ask them to rank the conclusions from best to worst.

Take feedback and use **Slide 7** to highlight the four main points to include in a competent conclusion.

Using **Slide 8**, ask students to create their own mnemonic, before sharing ours on **Slide 9**.

Use **Slides 13-14** to cover some other tips on how to write a meaningful conclusion.





For higher ability students, use **Slides 10-12** as an alternative to **Slides 7-9**.

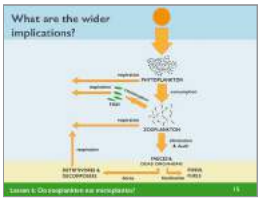
There is no 'right' answer to this, the conclusions each have different strengths.
The table summarises the conclusions strengths.

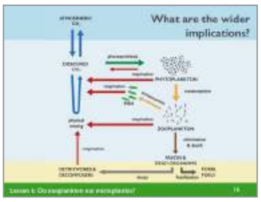
	1	2	3	4
Linked to hypothesis	✓	✓	✓	✓
Described pattern	✓	✓	✓	✓
Used numbers	n/a	n/a	n/a	n/a
Explained pattern		✓		
Explained a wider impact	✓		✓	
Explained limitations	✓			✓

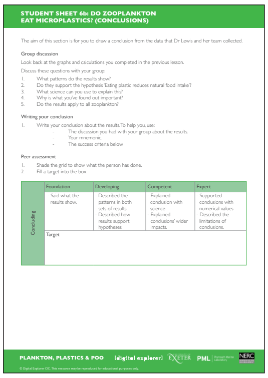
It's important that students understand that while Sara may have covered many of the points, her lack of formal language, actually makes her conclusion appear weaker.

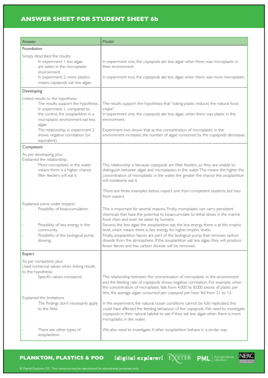
4

20 mins









Demonstrating learning: writing conclusions
The purpose of step 4 is for students to demonstrate their learning by drawing conclusions from the graphs they created in the previous lesson.

Hand out **Student Sheet 6b**. Ask students to use this to help them discuss, plan and write a draft conclusion.
Slides 15-17 can be used to help them consider the wider implications.
Ask students to swap their conclusions to get some peer feedback on their conclusions.
Ask students to write a neat draft of their conclusions.

Display **Answer Sheet 6b** on the board. Ask students to use this to complete the peer assessment section on **Student Sheet 6b**. Alternatively, use **Slides 18-20**.

Students should highlight the statements in the peer assessment grid to indicate what has been achieved, and then write a target in the target box.

5

5 mins

The purpose of Step 5 is for students to reflect on their learning and place it back into context.

Final learning check point (Assessment for Learning).

Ask students to complete the reflection questions on **Slide 21**. Take feedback from the class.

Round off the lesson by reading the final thoughts from Dr Matt Cole on **Slide 22**.

STUDENT SHEET 6a: MODEL CONCLUSIONS: ZOOPLANKTON AND MICROPLASTICS

Part 1 - Observing

Before you start, make sure you have answered the discussion questions on: Student Sheet 5a Do zooplankton eat microplastic? (Practical).

You can record your observations in the table below:

Beaker	Gut contents (colour)	Gut contents (texture)
A (algae only)		
B (microplastic only)		
C (algae and microplastic)		

Part 2 - Concluding

1. Cut out the conclusions below: they were made by students who have performed the same experiment as you.
2. Rank the conclusions from best to worst.
3. Consider reasons why you have placed them in this order and be prepared to justify your decision.

1. Sara
The results support the hypothesis because they show the shrimp ate microplastic. This means that zooplankton eat microplastic. Microplastic is a problem because zooplankton eat it, which could kill them or make them eat less. This could damage the community. We don't know if wild shrimp also eat microplastic, so we need to test this further.

2. Alesha
The results support the hypothesis that zooplankton eat microplastic because we found microplastic beads in the guts of the shrimp. Brine shrimp are filter feeders, they 'sieve' their meals out of the water column. This experiment shows that they are unable to distinguish between microplastic and algae of the same size.

3. Martin
The shrimp in the mixed algae and microplastic solution had both algae and microplastic in their guts. This supports the hypothesis that zooplankton eat microplastic. This is important because of the role shrimp and other zooplankton play in the community. They are a food source for many marine animals and their faeces are an important part of the biological pump that removes CO_2 from the atmosphere.

4. Pakesh
The results support the hypothesis that zooplankton eat microplastic because we found microplastic beads in the guts of the shrimp kept in the mixed algae and microplastic solution. However, this does not mean that brine shrimp in the wild eat microplastic. They might be able to move to water with less microplastic and avoid eating it altogether, which they could not do in our experiment. Also, there are other types of zooplankton who may not eat microplastic. The next steps in testing the hypothesis are to go into the field and see if shrimp in the ocean have microplastic in their guts, and to repeat the lab experiment with other types of zooplankton.

STUDENT SHEET 6b: DO ZOOPLANKTON EAT MICROPLASTICS? (CONCLUSIONS)

The aim of this section is for you to draw a conclusion from the data that Dr Lewis and her team collected.

Group discussion

Look back at the graphs and calculations you completed in the previous lesson.

Discuss these questions with your group:

1. What patterns do the results show?
2. Do they support the hypothesis 'Eating plastic reduces natural food intake'?
3. What science can you use to explain this?
4. Why is what you've found out important?
5. Do the results apply to all zooplankton?

Writing your conclusion

1. Write your conclusion about the results. To help you, use:
    - The discussion you had with your group about the results.
    - Your mnemonic.
    - The success criteria below.

Peer assessment

1. Shade the grid to show what the person has done.
2. Fill a target into the box.

	Foundation	Developing	Competent	Expert
Concluding	- Said what the results show.	- Described the patterns in both sets of results. - Described how results support hypotheses.	- Explained conclusion with science. - Explained conclusions' wider impacts.	- Supported conclusions with numerical values. - Described the limitations of conclusions.
	Target			

ANSWER SHEET FOR STUDENT SHEET 6b

Answer	Model
Foundation Simply described the results: - In experiment 1 less algae are eaten in the microplastic environment. - In experiment 2, more plastics means copepods eat less algae.	In experiment one, the copepods ate less algae when there was microplastic in their environment. In experiment two, the copepods ate less algae when there was more microplastic.
Developing Linked results to the hypothesis: - The results support the hypothesis. - In experiment 1, compared to the control, the zooplankton in a microplastic environment eat less algae. - The relationship in experiment 2 shows negative correlation (or equivalent).	The results support the hypothesis that "eating plastic reduces the natural food intake". In experiment one, the copepods ate less algae, when there was plastic in the environment. Experiment two shows that as the concentration of microplastic in the environment increases, the number of algae consumed by the copepods decreases.
Competent As per developing, plus: Explained the relationship: - More microplastic in the water means there is a higher chance filter feeders will eat it. Explained some wider impacts: - Possibility of bioaccumulation. - Possibility of less energy in the community. - Possibility of the biological pump slowing.	This relationship is because copepods are filter feeders, so they are unable to distinguish between algae and microplastics in the water. This means the higher the concentration of microplastic in the water, the greater the chance the zooplankton will mistakenly eat it. *There are three examples below, expect one from competent students, but two from expert.* This is important for several reasons. Firstly, microplastic can carry persistent chemicals that have the potential to bioaccumulate to lethal doses in the marine food chain and even be eaten by humans. Second, the less algae the zooplankton eat, the less energy there is at this trophic level, which means there is less energy for higher trophic levels. Finally, zooplankton faeces are part of the biological pump that removes carbon dioxide from the atmosphere. If the zooplankton eat less algae, they will produce fewer faeces and less carbon dioxide will be removed.
Expert As per competent, plus: Used numerical values when linking results to the hypothesis: - Specific values compared. Explained the limitations - The findings don't necessarily apply to the field. - There are other types of zooplankton.	The relationship between the concentration of microplastic in the environment and the feeding rate of copepods shows negative correlation. For example, when the concentration of microplastic falls from 4,000 to 8,000 pieces of plastic per litre, the average algae consumed per copepod per hour fell from 21 to 12. In the experiment, the natural ocean conditions cannot be fully replicated, this could have affected the feeding behaviour of the copepods. We need to investigate copepods in their natural habitat to see if they eat less algae when there is more microplastic in the water. We also need to investigate if other zooplankton behave in a similar way.

Lesson 7:

How can you make sure your discoveries have an impact?

Having made their discovery that microplastics affect zooplankton feeding and that this could have devastating environmental consequences, the question is, what changes do they want to see, and who should make them?

Resources in this booklet:

Lesson Overview 7

Teacher Guidance 7

Student Sheet 7a Reducing the impacts of microplastics

Student Sheet 7b Communications ideas

Student Sheet 7c Impact plan

Student Sheet 7d SMART targets

Resources available online:

Slideshow 7 available at bit.ly/PPP_SL

Video 4 Science and society available at bit.ly/PPP_Vid4

LESSON 7: HOW CAN YOU MAKE SURE YOUR DISCOVERIES HAVE AN IMPACT?

Lesson overview

Having made their discovery that microplastics affect zooplankton feeding and that this could have devastating environmental consequences, the question is, what changes do they want to see, and who should make them?

Details

Time
60 minutes

Specification links
Working scientifically
- Wider impacts of science.
- Communicating science.

Age
14-16 / GCSE Biology / GCSE Combined Science

Key words

Names audience, impact, SMART target

Concepts charismatic megafauna, communication

Lesson steps

Step	Lesson steps	Learning outcomes
1 10 mins	**Brief from Dr Ceri Lewis** Use the slides to set the context and share the learning outcomes. Use the video to discuss the wider context and introduce some of the lesson ideas.	Understand the wider context and the learning outcomes.
2 10 mins	**The 'Bambi effect'** Use the slide to illustrate the concept of 'charismatic megafauna' leading into the idea that while zooplankton aren't pretty, they are vital and it's the students' job to tell other people why.	Understand the wider context and the learning outcomes.
3 5 mins	**How do scientist have an impact?** Students learn how the research part of a scientist's work is only part of the story and understand the variety of 'pathways to impact' available to researchers. In this lesson, students will work in small groups to address the public engagement strand, ie working to have an impact on society.	**Foundation** Give some ways scientific discoveries can have an impact. **Developing, Competent, Expert** Produce & implement an impact plan.
4 20 mins	**Producing an impact plan** Student groups develop an impact plan, considering the change they want to see, their target audience, and the communications methods they will use to bring this change about.	As above.
5 10 mins	**SMART targets** Each group creates SMART targets to help them deliver their plans.	As above.
6 5 mins	**Pledge and self-reflection** Students finish the lesson by pledging to deliver their impact plans and reducing the amount of microplastics entering the marine environment.	Reflect on learning.

Resources

Student Sheets

Student Sheet 7a
Reducing the impacts of microplastics

Student Sheet 7b
Communications ideas

Student Sheet 7c
Impact plan

Student Sheet 7d
SMART targets

Slideshow

Slideshow 7
Science and society

Videos

Video 4
Science and society

Home learning

Students implement their action plans.

Flip it
Ask students to watch the video prior to the lesson and answer the questions on one of the video worksheets.

Differentiation

By outcome
The open summary assessment task allow students to demonstrate their learning at any level.

By support
See the Teacher Guidance for more ideas.

Step

1

10 mins

Contextualising learning
The purpose of Step 1 is to share the learning outcomes, set the context and engage students with the learning.

Ask students to write the lesson title from the top left of **Slide 1** as well as the date and key question into their books. They can then try to guess the missing word from the key question, which in this case is "impact".
Read the outcomes on **Slide 2** with the students and ask them to put their hands up to show what they can already do.
Link this lesson to previous learning using **Slide 3**.

Challenge students who you think are over or underestimating their current learning by asking targeted questions.

Read the topic brief from Dr Ceri Lewis on **Slide 4** to put the lesson into context.

This is a good opportunity for students to take the lead and practise reading aloud.

Show students **Video 4 Science and society**. This introduces some of the societal issues and dilemmas surrounding the use of plastics and their impact on the marine environment.

Ask students to summarise the video in 10 words or less and take some examples from the class.

Video 4 can also be set as home learning to watch before the lesson. The two relevant Student Sheets are linked in the video description or can be found in the Video Lessons section of the Resources booklet. One is a simple recall activity, the other takes a more reflective approach to learning from videos. An Answer Sheet for the recall questions is also included.

2

10 mins

Developing ideas: the 'Bambi effect'
The purpose of **Step 2** is to debate some of the issues surrounding public engagement on ecological issues.

Show students the images on **Slide 5**. Pose the question to the class. Students should be pushed to justify or explain their opinions.
Repeat this for the question on **Slide 6**.
Ask students whether they think that their answers to these two questions could pose a problem to taking appropriate environmental action.
Use **Slide 7** to relate the discussion back towards creating an impact plan for research into marine microplastics.

Many environmental groups use the 'bambi effect' and feature 'charismatic megafauna' in their campaigns. This is based on the belief that the general public care more for cute animals than on conservation priorities. Some people feel that this approach skews research and conservation funding.

TEACHER GUIDANCE 7: HOW CAN YOU MAKE SURE YOUR DISCOVERIES HAVE AN IMPACT?

Step

3

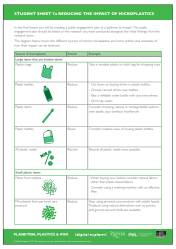
5 mins

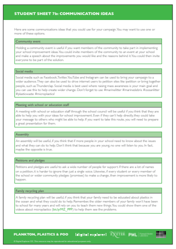
Developing ideas: how scientists have an impact
The purpose of Step 3 is for students to introduce the idea of pathways to impact to students. For more background information on Pathways to impact see the RCUK website http://www.rcuk.ac.uk/innovation/impacts/.

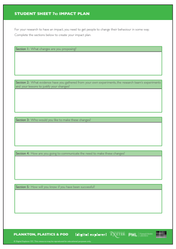
Use **Slide 8** to describe the research process. This is a simplified version and does not describe the research proposal and funding stage nor the intricacies of the peer review process.
Use **Slide 9** to introduce students to the type of questions that scientists need to pose to develop an impact plan. **Slide 10** shows the main pathways to impact. Row 1 shows impact within the scientific community. Row 2 focuses on policy change. Row 3 looks at how research can drive commercial innovation. Row 4 focuses on the public engagement strand. **Slide 11** highlights to students that this will be their area of focus for the impact plan that they will develop in this lesson.

4

20 mins







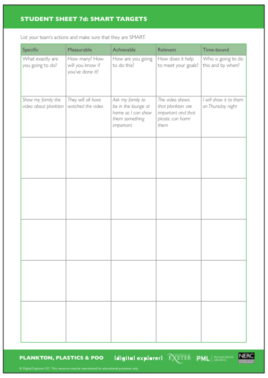
Developing ideas: impact plan
The purpose of Step 4 is for students to develop their own impact plan.

Divide students into groups of 3 to 4. Hand out a copy of each of **Student Sheets 7a, 7b and 7c** to each group. Using **Slides 12-15**, outline the process of developing an impact plan. In particular, use **Slide 13** to point out key features on **Student Sheet 7a Reducing the impact of microplastics**, and **Slide 15** to review some of the ideas on **Student Sheet 7b Communications ideas**.

Students use the information and ideas on **Student Sheets 7a and 7b** to complete their impact plan using the lay out and prompt questions on **Student Sheet 7c Impact plan**.

5

10 mins



Developing ideas: SMART targets
The purpose of Step 5 is to introduce students to the idea of SMART targets to ensure that they deliver on their impact plans.

Hand out a copy of **Student Sheet 7d SMART targets** to each student group. Use **Slide 16** to introduce students to the idea of SMART targets.

Students complete their SMART targets and assign tasks as a group.

Step

6

5 mins

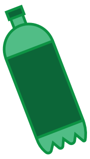
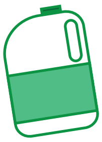
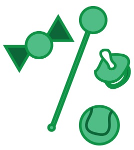
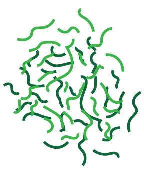
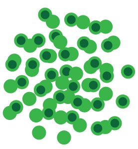
Reflect on learning
Step 6 brings the unit of work to a close with students pledging to continue to work for societal change based on scientific research.

Use the quote on **Slide 17** to lead into each group using their impact plan to share a pledge to create a lasting impact from their study of zooplankton and microplastics.

STUDENT SHEET 7a REDUCING THE IMPACT OF MICROPLASTICS

In this final lesson you will be creating a public engagement plan as a 'pathway to impact'. This public engagement plan should be based on the research you have conducted alongside the initial findings from the research team.

The diagram below shows the different sources of marine microplastics and some actions and examples of how their impact can be lessened.

Source of microplastic	Action	Example
Large items that are broken down		
Plastics bags 	Reduce	Take a reusable plastic or cloth bag for shopping trips.
Plastic bottles 	Reduce	- Cut down on buying drinks in plastic bottles. - Choose canned drinks over bottles. - Take a refillable water bottle with you everywhere. - Drink tap water.
Plastic items 	Reduce	Consider choosing natural or biodegradable options over plastic, eg a bamboo toothbrush.
Plastic bottles 	Reuse	Consider creative ways of reusing plastic bottles.
All plastic waste 	Recycle	Recycle all plastic waste were possible.
Small plastic items		
Fibres from clothes 	Reduce	- When buying new clothes consider natural fabrics rather than plastic-based fabrics. - Consider using a washing machine with an effective filter.
Microbeads from personal care products 	Reduce	Stop using personal care products with plastic beads. Products using natural alternatives such as pumice and ground almond shells are available.

STUDENT SHEET 7b: COMMUNICATION IDEAS

Here are some communications ideas that you could use for your campaign. You may want to use one or more of these options.

Community event
Holding a community event is useful if you want members of the community to take part in implementing your school improvement ideas. You could invite members of the community to an event at your school and make a speech about the improvements you would like and the reasons behind it. You could then invite everyone to be part of the solution.

Social media
Social media such as Facebook, Twitter, YouTube and Instagram can be used to bring your campaign to a wider audience. They can also be used to drive internet users to petition sites like ipetition or bring together people, such as Thunderclap. Social media is best used where raising mass awareness is your main goal and you can use this to help create wider change. Don't forget to use #marinelitter #marinedebris #oceanlitter #plasticwaste #microplastics!

Meeting with school or education staff
A meeting with school or education staff through the school council will be useful if you think that they are able to help you with your ideas for school improvement. Even if they can't help directly, they could take your message to others who might be able to help. If you want to take this route, you will need to prepare a great presentation for them.

Assembly
An assembly will be useful, if you think that if more people in your school need to know about the issues and what they can do to help. Don't think that because you are young, no one will listen to you. In fact, maybe the opposite is true.

Petitions and pledges
Petitions and pledges are useful to ask a wide number of people for support. If there are a lot of names on a petition, it is harder to ignore than just a single voice. Likewise, if every student or every member of the school or wider community pledges (promises) to make a change, then improvement is more likely to happen.

Family recycling plan
A family recycling plan will be useful, if you think that your family need to be educated about plastics in the ocean and what they could do to help. Remember, the older members of your family won't have been to school for many years and will rely on you to teach them new things. You could show them one of the videos about microplastics (bit.ly/MZ_PPP) to help them see the problems.

STUDENT SHEET 7c: IMPACT PLAN

For your research to have an impact, you need to get people to change their behaviour in some way .

Complete the sections below to create your impact plan.

Section 1: What changes are you proposing?

Section 2: What evidence have you gathered from your own experiments, the research team's experiments and your lessons to justify your changes?

Section 3: Who would you like to make these changes?

Section 4: How are you going to communicate the need to make these changes?

Section 5: How will you know if you have been successful?

STUDENT SHEET 7d: SMART TARGETS

List your team's actions and make sure that they are SMART.

Specific	Measurable	Achievable	Relevant	Time-bound
What exactly are you going to do?	How many? How will you know if you've done it?	How are you going to do this?	How does it help to meet your goals?	Who is going to do this and by when?
Show my family the video about plankton	*They will all have watched the video*	*Ask my family to be in the lounge at home so I can show them something important*	*The video shows that plankton are important and that plastic can harm them*	*I will show it to them on Thursday night*

Video Lessons

These 'Working scientifically' films for GCSE Science allow students to develop their science skills through learning from a professional research team investigating the impact of microplastics on the marine ecosystem. The scientists from the University of Exeter and Plymouth Marine Laboratory are working to understand one of the most critical environmental issues facing the ocean. There are an estimated 5.25 trillion pieces of plastic in the ocean's surface waters and these plastic particles could have catastrophic consequences for the marine food web and carbon cycle. Follow the team as they journey out to collect samples in the field, analyse them in the lab and reflect on the importance of science and society.

Resources in this booklet:

- Video Lesson 1 Investigating the impact of microplastics
- Student Sheet Video 1
- Video Lesson 2 Science under sail
- Student Sheet Video 2
- Video Lesson 3 Science in the lab
- Student Sheet Video 3
- Video Lesson 4 Science and society
- Student Sheet Video 4
- Student Sheet Video reflection

Resources available online:

Video 1 Investigating the impact of microplastics available at bit.ly/PPP_Vid1
Video 2 Science under sail available at bit.ly/PPP_Vid2
Video 3 Science in the lab available at bit.ly/PPP_Vid3
Video 4 Science and society available at bit.ly/PPP_Vid4

VIDEO LESSON 1: INVESTIGATING THE IMPACT OF MICROPLASTICS

Video overview

Introducing the issue of marine plastics and their impact on the ocean ecosystem, this video looks at how scientists investigate environmental issues and the potential impact of human actions. Students will also be able to relate existing knowledge of the carbon cycle, food webs and human impacts on the environment to the work of a professional research group.

Details

Time
15-20 minutes

Specification links
Interdependence & Carbon cycle
AQA Trilogy: 4.7 Ecology
AQA Synergy: 4.4 Explaining change
OCR 21: B3 Living together
OCR Gateway: B4 Community level systems
Edexcel: B9 Ecosystems and material cycles

Age
14-16 / GCSE Biology / GCSE Combined Science

Learning outcomes

Explain the importance of zooplankton in a community and in the marine carbon cycle.

Evaluate the environmental implications of scientific research.

Learning options

This video lesson can be used as part of **Lessons 1 or 6** of the **Plankton, Plastics & Poo unit.** There are also opportunities to use a flipped approach to learning, setting the video lesson as pre-work before the topic is taught or as home learning to provide reinforcement of factual knowledge or to encourage further reflection.

Recall approach

- Use this approach to reinforce factual knowledge during a lesson or after the topic has been taught in class.
- Before starting the activity or setting home learning, hand out **Student Sheet Video 1** and review with students.
- Students watch the **Investigating the impact of microplastics video**, without taking notes or focusing on the questions.
- Students then look at the questions on **Student Sheet Video 1** and see if they can recall the answers.
- Students can watch the video again to improve their ability to answer the questions.
- Use the answers below to debrief the video during the lesson or in the next lesson if set for home learning. Students can also peer assess work.

Reflective approach

- Use this approach to encourage further reflection on topics and as pre-learning for topics to be taught in class.
- Before stating the activity or setting home learning, hand out **Student Sheet Video reflection**, and review with students.
- Students watch the **Investigating the impact of microplastics video**, without taking notes or focusing on the questions.
- Students then look at the questions on **Student Sheet Video reflection**, and see what they can answer, making any notes.
- Students can watch the video a second time and answer any of the points that they would still like to know.
- Students can share their thoughts and answers as part of a whole class discussion during the lesson or in the next lesson if set for home learning.

Resources

Student Sheet

Student Sheet Video 1

Student Sheet Video reflection

Videos

Video 1
Investigating the impact of microplastics
bit.ly/PPP_Vid1

Answers to Student Sheet Video 1

1. An estimated 28 million tons or 10% of all plastics made each year. **2.** Less than 5mm across. **3.** Plastic fragments, nurdles, synthetic fibres and personal care products. **4.** Because they are small enough to be eaten by a whole range of marine life. **5.** Copepods, a type of zooplankton, like a tiny shrimp. **6.** They are numerous (an estimated 1,347,000,000,000,000,000,000). They perform an important role at the bottom of the food chain. Copepods also play a role in the carbon cycle. **7.** There is 50 times as much carbon in the ocean compared to the atmosphere. **8.** Through physical processes such as ocean currents and through biological processes such as photosynthesis and defecation. **9.** If copepods eat plastic instead of algae they would not remove as much carbon from the upper ocean. In addition, the faecal pellets (poo) may not sink to the deep ocean. **10.** The aim of the research is to follow the journey of microplastics from human activity to copepods. Might copepods eating plastic have an impact on the wider marine environment? For example, will there be less food available to marine predators or have an impact on the marine carbon cycle.

STUDENT SHEET VIDEO 1

Watch the **Investigating the impact of microplastics** video at bit.ly/PPP_Vid1.

Answer all the questions below in your book. Watch the video again to improve your answers.

1. How much plastic ends up in the ocean each year?
2. What size are microplastics?
3. What types of microplastics are found in the ocean?
4. What is the main reason why scientists are worried about microplastics?
5. What animals are the scientists focusing on?
6. Why are these animals important?
7. How much carbon is there in the ocean compared to the atmosphere?
8. How does carbon move from the shallow ocean to the deep ocean?
9. What is the problem with plastics and plankton poo?
10. What is the aim of the research?

Watch the **Investigating the impact of microplastics** video at bit.ly/PPP_Vid1.

Answer all the questions below in your book. Watch the video again to improve your answers.

1. How much plastic ends up in the ocean each year?
2. What size are microplastics?
3. What types of microplastics are found in the ocean?
4. What is the main reason why scientists are worried about microplastics?
5. What animals are the scientists focusing on?
6. Why are these animals important?
7. How much carbon is there in the ocean compared to the atmosphere?
8. How does carbon move from the shallow ocean to the deep ocean?
9. What is the problem with plastics and plankton poo?
10. What is the aim of the research?

VIDEO LESSON 2: SCIENCE UNDER SAIL

Video overview

The scientists provide an insight into field sampling techniques. Join the plastics research team as they explain how to identify a research site and how to ensure that any samples collected can be used as valid data.

Details

Time
15-20 minutes

Specification links
Working scientifically
Sampling techniques

Age
14-16 / GCSE Biology / GCSE Combined Science

Learning outcomes

Describe how to collect data at sea.

Evaluate different sampling techniques.

Learning options

This video lesson can be used as part of **Lesson 4** of the **Plankton, Plastics & Poo unit.** There are also opportunities to use a flipped approach to learning, setting the video lesson as pre-work before the topic is taught or as home learning to provide reinforcement of factual knowledge or to encourage further reflection.

Recall approach

- Use this approach to reinforce factual knowledge during a lesson or after the topic has been taught in class.
- Before starting the activity or setting home learning, hand out **Student Sheet Video 2** and review with students.
- Students watch the **Science under sail video**, without taking notes or focusing on the questions.
- Students then look at the questions on **Student Sheet Video 2** and see if they can recall the answers.
- Students can watch the video again to improve their ability to answer the questions.
- Use the answers below to debrief the video during the lesson or in the next lesson if set for home learning. Students can also peer assess work.

Reflective approach

- Use this approach to encourage further reflection on topics and as pre-learning for topics to be taught in class.
- Before stating the activity or setting home learning, hand out **Student Sheet Video reflection**, and review with students.
- Students watch the **Science under sail video**, without taking notes or focusing on the questions.
- Students then look at the questions on **Student Sheet Video reflection**, and see what they can answer, making any notes.
- Students can watch the video a second time and answer any of the points that they would still like to know.
- Students can share their thoughts and answers as part of a whole class discussion during the lesson or in the next lesson if set for home learning.

Resources

Student Sheet

Student Sheet Video 2

Student Sheet Video reflection

Videos

Video 2
Science under sail
bit.ly/PPP_Vid2

Answers to Student Sheet Video 2

1. How much microplastic is in the sea and where it occurs. **2.** No, the science team has to go out into the 'real world' to answer questions. **3.** Less than 5mm across. **4.** They are focusing on the Gulf of Maine as this is where there are high concentrations of nutrients (ie a lot of plastics) and it is also near to coastal cities (so likely to be high levels of plastic waste). **5.** Neuston nets act like giant sieves, concentrating the plastics and plankton in the seawater. **6.** They need to know that the plastic in their samples comes from the ocean and not from their clothing and so they wear cotton clothes, use nitrile gloves and quickly cover their samples. **7.** Scientists need to do a fair test and base their analysis on the data they have found rather than relying on previous research. **8.** Microplastics and plankton are found in the same part of the ocean. **9.** Do the zooplankton actually eat the microplastics? **10.** The science team found 4,500 pieces of plastic.

STUDENT SHEET VIDEO 2

Watch the **Investigating the impact of microplastics** video at bit.ly/PPP_Vid2.

Answer all the questions below in your book. Watch the video again to improve your answers.

1. What is the question that the scientists want to answer?
2. Does all science happen in the laboratory?
3. How large are microplastics?
4. Where are the scientists sampling and why?
5. How are the neuston nets used?
6. How do the scientists ensure their data is valid?
7. Why is it important for scientists not to have preconceived ideas about their research?
8. What was the scientists' key finding?
9. What remaining questions do the scientists have?
10. How much plastic did the scientists find?

Watch the **Investigating the impact of microplastics** video at bit.ly/PPP_Vid2.

Answer all the questions below in your book. Watch the video again to improve your answers.

1. What is the question that the scientists want to answer?
2. Does all science happen in the laboratory?
3. How large are microplastics?
4. Where are the scientists sampling and why?
5. How are the neuston nets used?
6. How do the scientists ensure their data is valid?
7. Why is it important for scientists not to have preconceived ideas about their research?
8. What was the scientists' key finding?
9. What remaining questions do the scientists have?
10. How much plastic did the scientists find?

VIDEO LESSON 3: SCIENCE IN THE LAB

Video overview

The science team explain how laboratory work can complement field sampling. Learn how these experiments allow for controlling variables (ie experimental constants) and how the scientists design their experiments using the idea of a fair test.

Details

Time
15-20 minutes

Specification links
Working scientifically
Evaluate methods
Develop hypotheses
Appropriate and safe experiments

Age
14-16 / GCSE Biology / GCSE Combined Science

Learning outcomes

Evaluate laboratory techniques for validity of evidence.

Understand how hypotheses are developed and tested.

Learning options

This video lesson can be used as part of **Lesson 5** of the **Plankton, Plastics & Poo unit**. There are also opportunities to use a flipped approach to learning, setting the video lesson as pre-work before the topic is taught or as home learning to provide reinforcement of factual knowledge or to encourage further reflection.

Recall approach

- Use this approach to reinforce factual knowledge during a lesson or after the topic has been taught in class.
- Before starting the activity or setting home learning, hand out **Student Sheet Video 3** and review with students.
- Students watch the **Science in the lab video**, without taking notes or focusing on the questions.
- Students then look at the questions on **Student Sheet Video 3** and see if they can recall the answers.
- Students can watch the video again to improve their ability to answer the questions.
- Use the answers below to debrief the video during the lesson or in the next lesson if set for home learning. Students can also peer assess work.

Reflective approach

- Use this approach to encourage further reflection on topics and as pre-learning for topics to be taught in class.
- Before stating the activity or setting home learning, hand out **Student Sheet Video reflection**, and review with students.
- Students watch the **Science in the lab video**, without taking notes or focusing on the questions.
- Students then look at the questions on **Student Sheet Video reflection**, and see what they can answer, making any notes.
- Students can watch the video a second time and answer any of the points that they would still like to know.
- Students can share their thoughts and answers as part of a whole class discussion during the lesson or in the next lesson if set for home learning.

Resources

Student Sheet

Student Sheet Video 3

Student Sheet Video reflection

Videos

Video 3
Science in the lab
bit.ly/PPP_Vid3

Answers to Student Sheet Video 3

1. Microplastics occur in large numbers in the same parts of the ocean as zooplankton. **2**. To see whether the zooplankton are actually eating the microplastics. **3**. If copepods eat microplastics. **4**. The ability to control conditions and the availability of sophisticated equipment. **5**. By using a suitable number of replicates and by controlling variables such as temperature, food availability, volume of seawater, concentration of plastic beads, and the number of copepods. **6**. There was no variation in response—all the copepods ate the microplastics. **7**. If eating plastic reduces natural food intake. **8**. The scientists used 5 control beakers with just copepods, seawater and algae and 5 experimental beakers with microplastics as well. They measured how much food (algae) was eaten in each beaker. **9**. The presence of microplastics meant that copepods ate less food (algae). This is important because animals need food to provide energy for reproduction, survival and growth.

STUDENT SHEET VIDEO 3

Watch the **Science in the lab** video at bit.ly/PPP_Vid3.

Answer all the questions below in your book. Watch the video again to improve your answers.

1. What have research team learnt from their fieldwork?
2. Why are controlled laboratory experiments needed?
3. What is the first hypothesis that the scientists are testing?
4. What are the benefits of laboratory work over fieldwork?
5. How do the scientists design a fair test?
6. Why do scientists feel they can accept this first hypothesis?
7. What is the second hypothesis that the scientists tested?
8. How did the scientists test this hypothesis?
9. What did the scientists find?

Watch the **Science in the lab** video at bit.ly/PPP_Vid3.

Answer all the questions below in your book. Watch the video again to improve your answers.

1. What have research team learnt from their fieldwork?
2. Why are controlled laboratory experiments needed?
3. What is the first hypothesis that the scientists are testing?
4. What are the benefits of laboratory work over fieldwork?
5. How do the scientists design a fair test?
6. Why do scientists feel they can accept this first hypothesis?
7. What is the second hypothesis that the scientists tested?
8. How did the scientists test this hypothesis?
9. What did the scientists find?

VIDEO LESSON 4: SCIENCE AND SOCIETY

Video overview

The science team explain the societal importance of their work and how their research can be used by policy-makers, community organisations and wider society. The video can be used as a stimulus to a larger discussion about the impact of plastics on the environment and how science can help inform decisions about the future use of plastic.

Details

Time
15-20 minutes

Specification links
Working scientifically
Wider impacts of science
Communicating science

Age
14-16 / GCSE Biology / GCSE Combined Science

Learning outcomes

Understand the peer review process.

Debate the wider implications of science for society.

Describe ways that science can have a wider impact.

Learning options

This video lesson can be used as part of **Lesson 7** of the **Plankton, Plastics & Poo unit.** There are also opportunities to use a flipped approach to learning, setting the video lesson as pre-work before the topic is taught or as home learning to provide reinforcement of factual knowledge or to encourage further reflection.

Recall approach

Use this approach to reinforce factual knowledge during a lesson or after the topic has been taught in class.

Before starting the activity or setting home learning, hand out **Student Sheet Video 4** and review with students.

Students watch the **Science and society video**, without taking notes or focusing on the questions.

Students then look at the questions on **Student Sheet Video 4** and see if they can recall the answers.

Students can watch the video again to improve their ability to answer the questions.

Use the answers below to debrief the video during the lesson or in the next lesson if set for home learning. Students can also peer assess work.

Reflective approach

Use this approach to encourage further reflection on topics and as pre-learning for topics to be taught in class.

Before stating the activity or setting home learning, hand out **Student Sheet Video reflection**, and review with students.

Students watch the **Science and society video**, without taking notes or focusing on the questions.

Students then look at the questions on **Student Sheet Video reflection**, and see what they can answer, making any notes.

Students can watch the video a second time and answer any of the points that they would still like to know.

Students can share their thoughts and answers as part of a whole class discussion during the lesson or in the next lesson if set for home learning.

Resources

Student Sheet

Student Sheet Video 4

Student Sheet Video reflection

Videos

Video 4
Science and society
bit.ly/PPP_Vid4

Answers to Student Sheet Video 4

1. They are designed to last for a long time, but we use them once and then throw them away, so they persist in the environment. **2.** Communicate their findings to other stakeholders including other scientists, the public and policy makers, eg government. **3.** Plastics are used in areas such as medicine, construction and transport. **4.** 30% because these products are used once and then thrown away. **5.** Cutting down on plastic packaging; organising and taking part in beach cleans; and giving evidence to policy makers. **6.** The scientists featured do not think that plastic should be banned as it has many useful applications, but they do think that our approach to plastic should change and that we should aim to reduce plastic consumption, recycle and reuse as much as possible.

Questions for group or whole class discussion

1. When was the last time you bought a plastic item, including packaging?
2. How long do you think you could go without plastic for?

Watch the **Science and society** video at bit.ly/PPP_Vid4.

Answer all the questions below in your book. Watch the video again to improve your answers.

1. What are the problems with plastic?
2. What duty do scientists have after they have collected the data?
3. What are the benefits of plastic?
4. How much of global plastic production is used for packaging and why is this a problem?
5. List some of the actions that individuals in the film are taking to reduce the impact of plastics on the environment.
6. Do the scientists featured think that plastic should be banned? What reasons do they give?
7. When was the last time you bought a plastic item, including packaging?
8. How long do you think you could go without plastic for?

Watch the **Science and society** video at bit.ly/PPP_Vid4.

Answer all the questions below in your book. Watch the video again to improve your answers.

1. What are the problems with plastic?
2. What duty do scientists have after they have collected the data?
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6. Do the scientists featured think that plastic should be banned? What reasons do they give?
7. When was the last time you bought a plastic item, including packaging?
8. How long do you think you could go without plastic for?

STUDENT SHEET VIDEO REFLECTION

Reflect on the video you have just watched and make notes in the four boxes below.

When you watch the video a second time, see if you can answer some of the questions you have listed in the 'I still want to know' section.

I learnt…	I still want to know…

This changed my mind…	This relates to my experience of science…

Subject Updates

The subject updates are designed to give you, the teacher, the confidence you need to deliver some of the newer course content.

Resources in this booklet:

- Subject Update 1: Copepods
- Subject Update 2: The marine carbon cycle
- Subject Update 3: Trophic cascades
- Subject Update 4: Marine plastics
- Subject Update 5: Marine plastics facts and figures
- Useful websites
- Glossary
- Glossary (student version)

SUBJECT UPDATE 1: COPEPODS

A copepod is a small marine animal. It is a crustacean, which means it is related to lobsters, shrimps and crabs. Copepods are plankton, animals (zooplankton) and plants (phytoplankton) that are carried by ocean currents rather than making their own way in the world.

The word copepod comes from two Greek words *kope*- oar and *pod*- foot. These are the oar-footed creatures and they are the most abundant animal on this planet.

There are an estimated 1,347,000,000,000,000,000,000 copepods in the world's oceans.

They would fill over 80 million Olympic swimming pools and weigh more than 16 billion double-decker buses.

If you placed them end to end, they would stretch to the moon and back 87 million times.

There are nearly 200 billion more copepods than people on the planet, and even though they are small, their combined mass is over 400 times that of the human population.

At their fastest, they travel a hundred times faster than Usain Bolt. My little babies rock!

Not only are there a lot of them, they are also essential for the marine food chain. In any food chain there are the 'primary producers', life forms that take energy from the sun and turn it into carbohydrates, simple food. In the seas, this is algae, which are anything from single-celled phytoplankton to hundred foot long kelps and meadows of sea grass. This marine plant life does not generally contain the more complex carbohydrates, fats and proteins needed to sustain larger animals.

Copepods are secondary producers, gobbling algae gathered by their front three pairs of legs, and turning this into the more complex building blocks needed for larger marine life. They feed at night, avoiding their natural predators of krill, fish and baleen whales. During the day they can tail-flick as much as 500 metres down out of sight: a journey equivalent to you or I travelling from John O'Groats to Lands' End on a daily basis, a 1,400 mile round trip.

Dr Ceri Lewis

SUBJECT UPDATE 2: THE MARINE CARBON CYCLE

Where is the carbon?

There are four major carbon stores on the planet. The ocean contains the bulk of the world's carbon with 38,855 GtC (Gigatonnes of carbon). The next largest store is in soil and sediment. This includes soil, fossil fuel deposits, marine sediment, permafrost and carbonate minerals such as chalk and limestone. Carbon is also stored in living things such as plants and animals. The store most debated in the news is the atmospheric store, accountable for climate change.

Carbon sinks

Carbon sinks refer to the net uptake of carbon by terrestrial and marine ecosystems. The ocean acts as a carbon sink, absorbing 1.6 GtC per year. While this is beneficial for the levels of atmospheric carbon dioxide, there are potential ramifications with changes in ocean chemistry, through the process of ocean acidification.

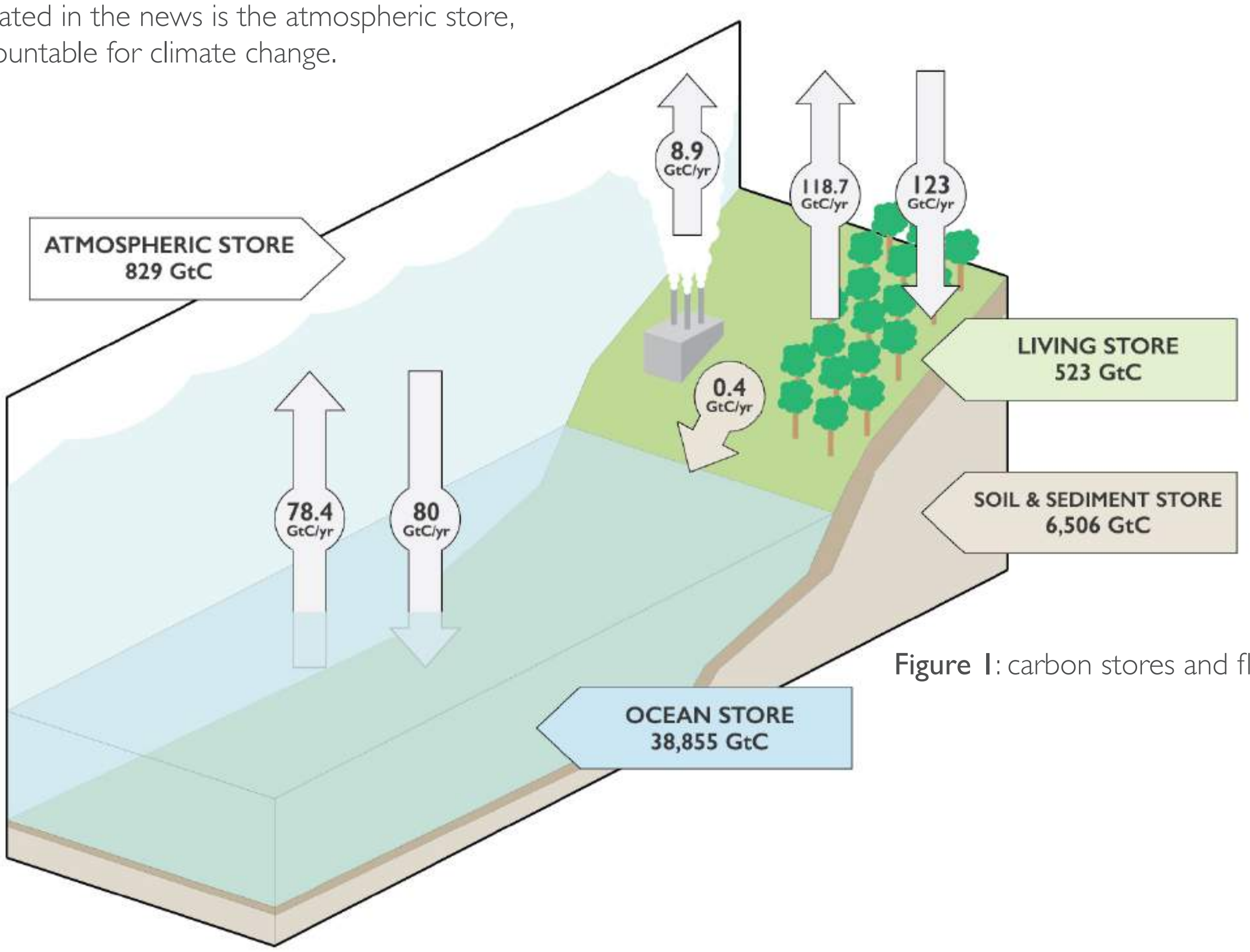


Figure 1: carbon stores and fluxes

Carbon fluxes

The arrows on Figure 1, above, show carbon fluxes, the movement of carbon between the stores in Gigatonnes per year.

From left to right, the arrows show:

78.4 GtC released from the ocean into the atmosphere each year.

80 GtC absorbed by the ocean from the atmosphere each year.

8.9 GtC released into the atmosphere through man-made or anthroprogenic activities, such as land use change, burning fossil fuels and cement manufacture.

0.4 GtC captured in sediment in the ocean and lakes through decay. This is a very slow process.

118.7 GtC released into the atmosphere through plant respiration each year.

123 GtC absorbed by terrestrial plants through photosynthesis each year.

All figures are consolidated mid-range figures from the IPCC AR5 report. Smaller fluxes, eg rock weathering and volcanism are not included.

How does carbon reach the bottom of the ocean?

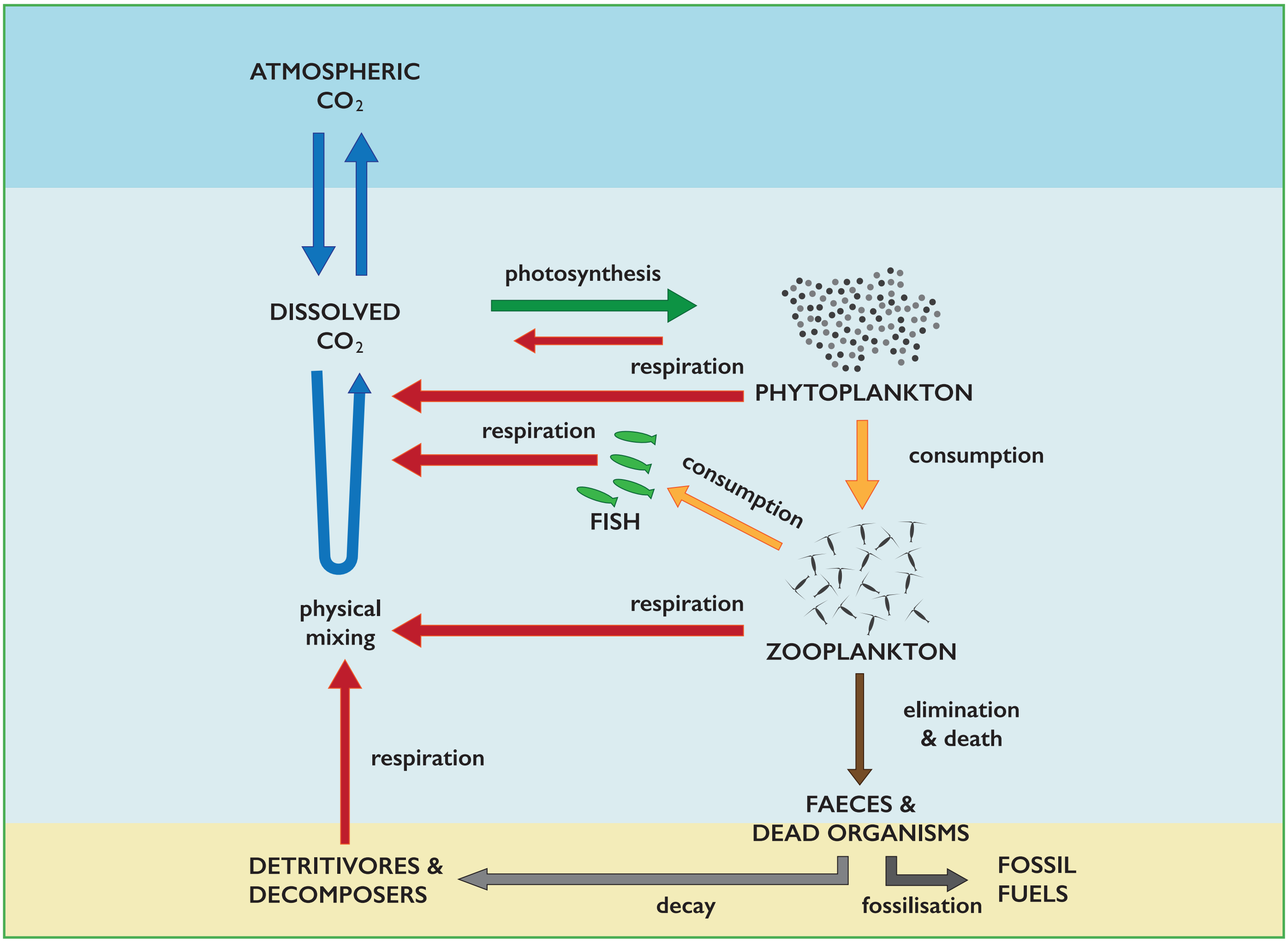


Figure 2: the physical and biological pumps

Carbon can take two routes to the ocean's depths, as shown in Figure 2. These routes are referred to as 'pumps'. The first, the 'physical pump', is a result of ocean water mixing due to currents. The second, the 'biological pump', is a result of feeding relationships and faeces production of zooplankton. Briefly:

1. Carbon is captured by phytoplankton in photosynthesis.
2. Carbon is transferred to zooplankton when they eat phytoplankton.
3. Carbon travels to the bottom of the ocean:
    a. In the faeces of zooplankton which sink.
    b. In dead zooplankton which sink.
    c. Some zooplankton also migrate vertically through the water column aiding the transfer of carbon to the deep ocean.
4. The organic material can be buried and through physical processes can become oil and natural gas.
5. In most cases however, the organic material is decomposed by detritivores and bacteria on the sea floor.
6. Carbon is also transferred to fish and other marine organisms in the food chain.
7. Carbon returns to the ocean from the biosphere at all levels through respiration.

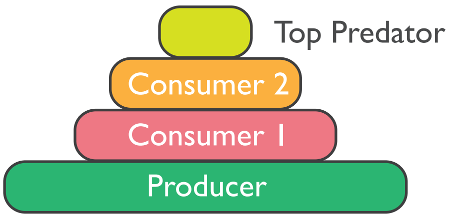
Trophic cascades occur when the change in the population density or removal of one species in a food chain has a knock on effect on the other species in the chain.

There are two types of cascade:

- **Top down cascades** caused by the population decline of a top predator.
- **Bottom up cascades** caused by the population decline of a producer or primary consumer.

Top down cascades

Before



After

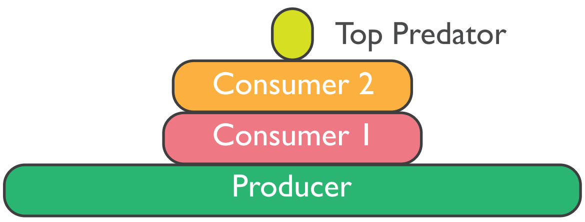


Figure 1: a model top down cascade. Note the bars are not to scale, rather indicative.

In top down cascades, as illustrated in Figure 1:

- The top predator population is severely reduced by human activity, eg over fishing;
- the secondary consumer population increases as it has been 'released from control' by predation;
- the primary consumer population decreases;
- the producer population increases.

Examples of top down cascades include:

- The over fishing of cod in the northwest Atlantic.
- The decimation of kelp forests by sea urchins after the mass hunting of sea otters who predate upon the urchins.

It's worth noting that these effects can vary over time.

While mid-level consumers might experience an initial population explosion, the resulting over feeding can drive their food sources to extinction, in turn causing their own demise.

Invasive species and top down cascades

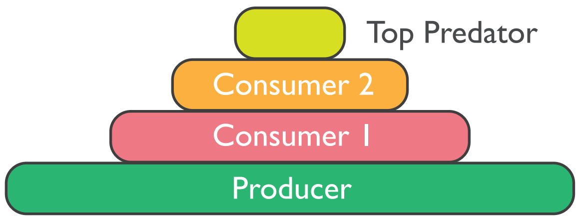
Another type of top down cascade can be caused by the introduction of an alien species, in so called 'invasive species' situations. There is growing concern for example about the impact of lionfish in the southern US coastal waters.

It's unclear how the lionfish were first introduced to the area. However, it's suspected that it happened at some point in the 1980s. The lionfish has an impact at lower trophic levels and it has been observed that a single lionfish can reduce juvenile reef fish populations by 79% in just five weeks.

The lionfish are free from control for two reasons. First, the species that would compete with them such as snappers and groupers have been heavily overfished. Second, the organisms that could predate upon them such as sharks, don't appear to have recognised the lionfish as prey as yet.

Bottom up cascades

Before



After

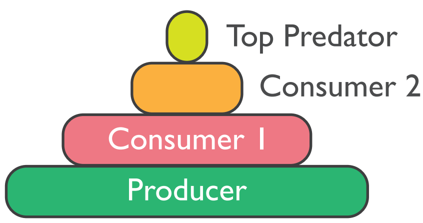


Figure 2: a model bottom up cascade. Note the bars are not to scale, rather indicative.

In a bottom up cascade, as illustrated in Figure 2, the producer population decreases, reducing the energy input into the system. As a result, there is a reduction in the population of all species at higher trophic levels.

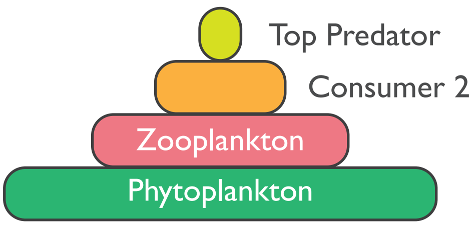
Cascades and microplastics

How could microplastics cause a cascade? The research team's results from the lab investigations show a negative correlation between the concentration of microplastic and the herbivory rates of zooplankton. This reduction in herbivory has the potential for two cascade effects, as shown in Figure 3.

First, phytoplankton levels could increase, as the population is released from the control of zooplankton herbivory.

Second, the reduction in energy into zooplankton at the second level, causes corresponding population declines at higher trophic levels. Whether this impact will actually be realised is an area for further research.

Before



After

Figure 3: Possible cascades caused by zooplankton grazing microplastics. Note the bars are not to scale, rather indicative.

Complexity

Biological systems are complex, and predicting the impact of changing populations is extremely difficult for a number of reasons.

Firstly, simple food chains are actually part of complex webs, with many interactions of different strengths, influenced by:

- The food preferences shown by both carnivores and herbivores.
- By many organisms occupying multiple trophic levels.
- By interactions where two organisms prey on each other at different phases of their life cycle.

Second, population density is also controlled by other factors, such as:

- The availability of breeding sites.
- The availability of refuges.
- Levels of disease.

Finally, communities are not discrete areas, they merge with those around them.

Further research

The precise community level impact of zooplankton grazing on microplastics obviously requires further study, but what is already clear is that human interactions which cause the decline of one population within a community, have a ripple effect that indirectly reduces that community's biodiversity.

The problem of plastic

Plastic debris has now become the most serious problem affecting the marine environment, not only for coastal areas but for the world's oceans as a whole.

Plastics are synthetic organic polymers. It is estimated that 4% of the world's annual petroleum production is converted to plastics while a similar amount is used to produce the energy for plastic manufacturing. The annual global production of plastics has doubled in the last 15 years to 280 million tons per year.

It has been estimated that plastics account for around 10% of the municipal waste stream with less than 10% of plastic being recycled. In the EU alone, 12.5 million tons of plastic is sent to landfill each year of which about half is packaging. The average plastic consumption in North America and Western Europe reached 100kg per person year in 2005 and is expected to increase to 140kg by 2015.

How does it reach the ocean?

About 28 million tons or 10% of all plastic produced each year ends up in the ocean. The sources of plastic fragments in the ocean are mainly the discharge of wastewater and runoff water from river systems and discarded plastic products from landfill. Other sources of marine plastics include the fishing industry, nautical activities and aquaculture.

The abundance of marine plastics in the ocean varies as a function of the distance to coastal populated areas and popular tourist destinations, as well as the occurrence of heavy rain and floods. The speed and direction of ocean surface currents also have an impact on the distribution of plastics.

What are the economic impacts of marine plastics?

Marine plastics are of particular concern to coastal cities and tourist destinations as plastic litter can reduce the area's attractiveness to local residents and visitors. Approximately £13 million is spent by English municipalities each year on removing marine litter. Previously popular tourist sites, Hawaii and the Maldives are threatened by a decline in tourist numbers and revenue due to dramatic pollution by marine debris. Plastic debris also affects the fishing and shipping industry, with English harbours spending £1.7 million each year to remove plastic debris that can foul propellers.

What impact do plastics have on the marine environment?

The impact of plastic debris on marine wildlife is widespread. At least 267 different species are known to have suffered from entanglement, suffocation or ingestion of marine debris including 86% of all turtle species, 44% of all seabird species and numerous marine invertebrates including amphipods, lugworms, barnacles and mussels.

Moreover, plastics can accumulate and transport toxic pollutants in the marine environment and this has been identified by the UNEP as one of the main emerging issues in the global environment.

UNIVERSITY OF EXETER
PML Plymouth Marine Laboratory
NERC SCIENCE OF THE ENVIRONMENT
Encounter Edu

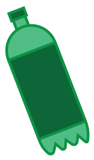
Plastic production

Over the last ten years we have produced more plastic than during the whole of the last century.

Plastic use

According to the British Plastics Federation, "the UK uses over 5 million tonnes of plastic each year of which an estimated 24% is currently being recovered or recycled".

According to Project Aware, 6.8 billion kg of plastic are produced in the USA every year, yet less than 7% of that is recycled.



It is estimated that in excess of 38 billion plastic bottles and 25 million Styrofoam cups end up in landfill and although plastic bottles are 100% recyclable, on average only 20% are actually recycled.

Annually approximately 500 billion plastic bags are used worldwide. More than one million bags are used every minute.

Enough plastic is thrown away each year to circle the earth four times.

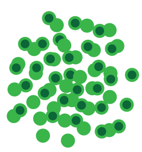
Plastic accounts for around 10% of the total waste we generate.

50 % of the plastic we use, we use just once and throw away.

Globally, we currently recover only 5% of the plastics we produce.

Plastic pollution

It is estimated that almost all of the marine pollution in the world is comprised of plastic materials. The average proportion varied between 60% and 80% of total marine pollution.



Plastic in the ocean breaks down into such small segments that pieces of plastic from a one litre bottle could end up on every mile of beach throughout the world.

It takes 500 to 1,000 years for plastic to degrade.

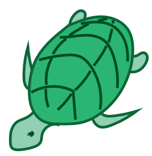
Tons of plastic can be found in swirling convergences in the oceans making up about 40% of the world's ocean surfaces. 80% of pollution enters the ocean from the land.

Land-based sources (such as agricultural run-off, discharge of nutrients and pesticides and untreated sewage including plastics) account for approximately 80% of marine pollution, globally.

Agricultural practices, coastal tourism, port and harbour developments, damming of rivers, urban development and construction, mining, fisheries, aquaculture, and manufacturing, among others, are all sources of marine pollution threatening coastal and marine habitats.

The United Nations Environment Programme estimated in 2006 that every square mile of ocean contains 46,000 pieces of floating plastic.

Plastic impacts



Scientists estimate that every year at least 1 million seabirds and 100,000 marine mammals and sea turtles die when they entangle themselves in plastic pollution or ingest it.

Some of these compounds found in plastic have been found to alter hormones or have other potential human health effects.

USEFUL WEBSITES

Science

University of Exeter Microplastics Research
The research group at the University of Exeter conducting this research.
www.exeter.ac.uk/research/feature/microplastics/

IUCN Plastic Debris in the Ocean Report
Summary report by the IUCN on the state of marine plastics and their environmental impact.
portals.iucn.org/library/node/44966

NGOs

Sea Musketeers
Believe in finding ocean solutions through education and adventure.
www.seamusketeer.com

Marine Conservation Society
The Marine Conservation Society say they are "the voice for everyone who loves the sea".
www.mcsuk.org/what_we_do/Clean+seas+and+beaches/Campaigns+and+policy/Microplastics

Beat the Bead
International campaign against plastic microbeads in cosmetics. There is also an app available.
www.beatthemicrobead.org/en/

Keep Britain Tidy
Beach clean ups organized as part of the BeachCare programme.
www.keepbritaintidy.org/beachcare/537/

TED talk by Captain Charles Moore
Capt Moore discovered the ocean garbage patch while sailing across the Pacific Ocean
www.ted.com/talks/capt_charles_moore_on_the_seas_of_plastic?language=en

Algalita Marine Research Foundation
NGO founded by Charles Moore to continue researching the issue of marine plastics and educate others.
www.algalita.org/

5 Gyres
5 Gyres organise research sailing expeditions, communicate the issue of marine plastics to the wider public and look for sustainable solutions to eliminate plastics pollution.
5gyres.org/

The British Plastics Federation
The professional body of the UK plastics industry.
www.bpf.co.uk/sustainability/plastics_recycling.aspx

News articles

US to ban soaps and other products containing microbeads, The Guardian
www.theguardian.com/us-news/2015/dec/08/us-to-ban-soaps-other-products-containing-microbeads

Why microbeads in shower gels are bad for marine life, BBC
www.bbc.co.uk/newsbeat/article/35261018/why-microbeads-in-shower-gels-are-bad-for-marine-life

Can the 'largest cleanup in history' save the ocean?, The Washington Post
http://wpo.st/O_zD1

Charting the plastic waters, The Economist
www.economist.com/news/science-and-technology/21635982-amount-plastic-sea-huge-and-widely-spread-charting-plastic

Plastic waste in ocean to increase tenfold by 2020, The Independent
www.independent.co.uk/environment/plastic-waste-in-ocean-to-increase-tenfold-by-2020-10042613.html

Plastic oceans: What do we know? BBC
www.bbc.co.uk/news/science-environment-34414710

First of Its Kind Map Reveals Extent of Ocean Plastics, National Geographic
news.nationalgeographic.com/news/2014/07/140715-ocean-plastic-debris-trash-pacific-garbage-patch/

Communications

Chiara Marina Grioni
A passionate diver and photographer who documented the Azores mission.
www.chiaraobscura.com/#!/index

Chris Jordan
Photographer specializing in social and environmental issues. This gallery is Midway: Message from the Gyre.
www.chrisjordan.com/gallery/midway/

Plastiki Expedition
Sailing expedition across the Pacific in a boat made out of thousands of plastics bottles.
archive.theplastiki.com/

Solutions

The Ocean Cleanup
Solution developed by Dutch teenager Boyan Slat.
www.theoceancleanup.com/

Natural Resources Defence Council
Ideas for individual and collective actions.
www.nrdc.org/oceans/plastic-ocean/

The 5p plastic bag charge: All you need to know, BBC
http://www.bbc.co.uk/news/uk-34346309

GLOSSARY

Accuracy	is a way of measuring how close a measurement is to the true value. The more accurate a result is, the closer it is to the true value.
Algae	plant-like life that lack the structures that plants have, such as leaves and roots. Algae includes small, single-celled examples known as micro-algae, and larger, often multi-celled examples such as seaweed, known as macro-algae.
Bias	a sample is biased when it does not truly reflect the whole population.
Bioaccumulation	the build-up of contaminants in organisms' tissues increases with trophic level.
Cod end	the instrument attached to the end of a trawling net to collect plastic debris or zooplankton.
Convergence zone	an area where strong ocean currents meet. These areas are often very biologically productive.
Copepod	a type of small shrimp-like plankton that performs an important role in the marine food web and carbon cycle. They are incredibly abundant, with an estimated 1,347 billion billion of them in the worlds' oceans.
Cruise	the name to given to a research voyage at sea. It may sound like a tropical holiday, but it is completely different.
Dose	the amount of a chemical in a organisms' tissues.
Gyre	a large system of rotating ocean currents, particularly those involved with surface winds.
Microplastic	plastic fragments that are less than 5mm across. They can consist of nurdles and larger items that have degraded.
Neuston net	a special type of net used to trawl the surface waters for evidence of plastics and plankton.
Nurdle	a small plastic bead used in the manufacturing process of plastic products, typically measuring less than 5mm across. Sometimes known as mermaid's tears when they are found washed up on beaches.
Persistent chemicals	chemicals that remain in the environment over long periods of time because they do not break down.
Phytoplankton	microscopic plants and algae that drift on the ocean currents.
Representative	a sample is representative if it is a true reflection of the whole population. Representative samples can be used to predict accurately features of the whole population.
Sample	a subset of a population.
Trawl	scientists use nets to collect data from the ocean. The use of these nets is known as trawling. These can be towed through surface waters such as the neuston nets in this research or different nets can be lowered deeper into the ocean, depending on the research being conducted.
Trophic cascade	trophic cascades occur when the change in the population density or removal of one species in a food chain has a knock on effect on the other species in the chain.
Zooplankton	small and microscopic eggs, larvae and animals that drift on the ocean currents.

GLOSSARY (STUDENT VERSION)

Accuracy

Algae

Bias

Bioaccumulation

Cod end

Convergence zone

Copepod

Cruise

Dose

Gyre

Microplastic

Neuston net

Nurdle

Persistent chemicals

Phytoplankton

Representative

Sample

Trawl

Trophic cascade

Zooplankton

All photography courtesy of University of Exeter, Plymouth Marine Laboratory and The Sea Musketeers.

This booklet and further ideas about bringing the ocean to your classroom are available for free download at **digitalexplorer.com**

This GCSE Science resource is based on an ongoing plastics project at the University of Exeter and Plymouth Marine Laboratory. The resource uses innovative methods to bring cutting edge science to the classroom, including:

- Using real field and laboratory data.
- Practicals that replicate the work of the scientists.
- Using social media to connect with the scientists.
- The opportunity to connect with scientists through Skype in the classroom events.
- A suite of multimedia resources available from **media.digitalexplorer.com**.

The topics covered are appropriate for students following the AQA Synergy and Trilogy, Edexcel and OCR 21st Century and Gateway specifications. They include:

- Interdependence.
- The carbon cycle.
- Human impact on biodiversity.
- Sampling techniques.
- Processing and presenting data.
- Interpreting data and concluding.
- Considering the wider implications of science.

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Plankton, Plastics, and Poo is an educational resource designed by Digital Explorer with the University of Exeter and funded by the Natural Environment Research Council.