

Impact case study (REF3)

Institution: University of Southampton		
Unit of Assessment: 07 Earth Systems and Environmental Sciences		
Title of case study: 07-01 Deep Impact: engaging public audiences and policymakers with the exploration and stewardship of biodiversity in the deep ocean		
Period when the underpinning research was undertaken: 2008 – present		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by HEI:
Jon Copley	Associate Professor in Ocean Exploration & Public Engagement	January 2000 – present
Rachel Mills	Professor of Ocean Chemistry	April 1993 – present
Leigh Marsh	Postdoctoral researcher	June 2014 – January 2017
Verity Nye	Postdoctoral researcher	October 2013 – February 2015
Period when the claimed impact occurred: August 2013 – December 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

By putting public engagement at the heart of our deep-sea research, we have delivered benefits to society by generating inspiration and curiosity about science, raising awareness of our research insights and their context, and providing cultural enrichment by supporting lifelong learning. We achieved these impact goals through a programme of activities including:

- working with broadcast documentary makers to feature findings from our research (e.g. underpinning research included in BBC *Blue Planet II*, now reaching ~1 billion worldwide);
- creating and delivering an interactive online programme to engage people with our research (e.g. a Massive Open Online Course with >52,000 enrolments from people in 183 countries);
- producing a popular science book highlighting our recent discoveries and delivering a related series of >70 in-person engagement events nationwide (to total audiences of >94,000 people);
- providing specific input to briefings and reports for UK policymakers, directly informing legislative recommendations for deep-sea mining with results from our research.

This overall programme of engagement with our research has raised wider awareness of the diversity of habitats and life in the deep ocean, the impacts of human activities on deep-sea environments, the potential of resources in the deep ocean, and the choices from personal to policy level that will determine its future.

2. Underpinning research

Deep ocean environments, defined as depths greater than 200 metres, cover more than 65 per cent of the surface of our planet and are under increasing pressure from human activities, such as the exploitation of their resources and the disposal of our waste. Our underpinning research explores the biodiversity and ecology of deep-sea environments, including their vulnerability to future activities such as deep-sea mining, supported by several NERC grants since 2008.

This programme of research has involved expeditions with UK research ships, including two led by Copley as Principal Scientist, using NERC's deep-diving Remotely Operated Vehicle. The multidisciplinary approach of the Southampton team, working with other UK and international partners, synthesises biological, geochemical, and geological data to provide a full environmental context for interpreting ecological patterns in deep-sea habitats. This has resulted in the following discoveries that underpin this Impact Case Study (research outputs [3.1 to 3.6] listed Section 3):

- the discovery and ecology of hydrothermal vents on the Mid-Cayman Spreading Centre of the Caribbean Sea [3.1], and the adaptations of a new shrimp species dominating those vents [3.2];
- the discovery and ecology of "black smoker" hydrothermal vents in the Southern Ocean [3.3], and the adaptations of a new crab species (the "Hoff" crab) that is abundant at those vents [3.4];
- the discovery of six previously undescribed species at hydrothermal vents on the Southwest Indian Ridge [3.5], and the adaptations of the abundant "scaly-foot snail" from those vents [3.6].

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3. References to the research

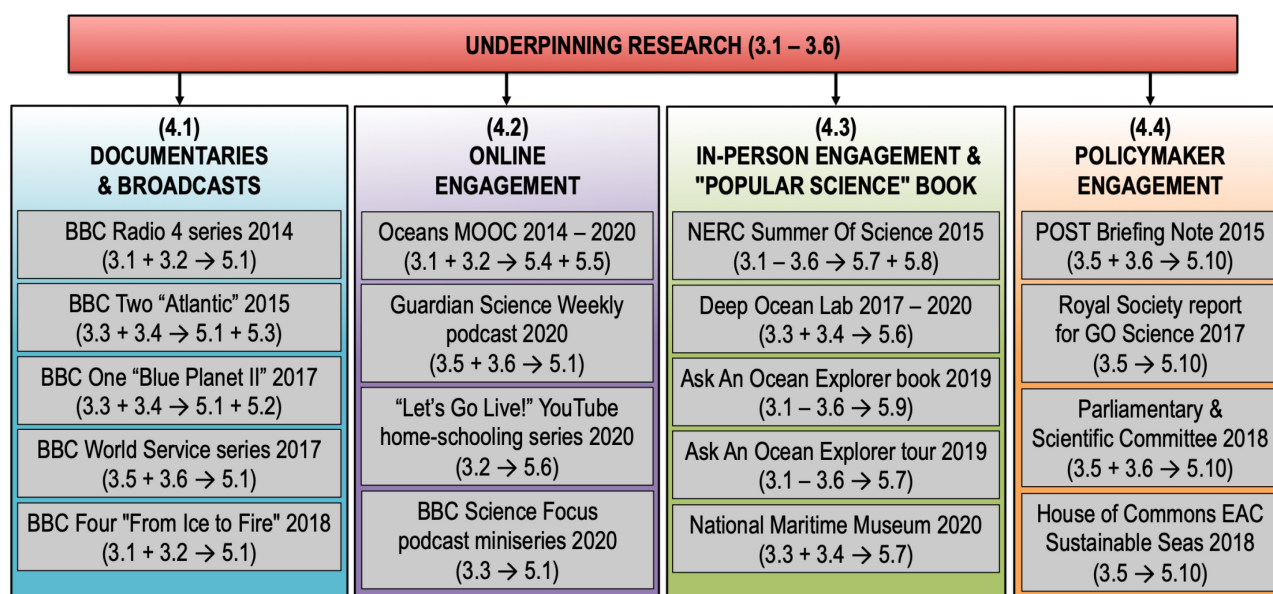
- 3.1:** Connelly D, **Copley J** [joint lead authors] *et al.* (2012). Hydrothermal vent fields and chemosynthetic biota on the world's deepest seafloor spreading centre. *Nature Communications*, **3**: 620 <https://doi.org/10.1038/ncomms1636>
- 3.2:** Nye V, **Copley J** & Plouviez S (2012). A new species of Rimicaris (Crustacea: Decapoda: Caridea: Alvinocarididae) from hydrothermal vent fields on the Mid-Cayman Spreading Centre, Caribbean. *Journal of the Marine Biological Association of the United Kingdom*, **92**: 1057-1072 <https://doi.org/10.1017/S0025315411002001>
- 3.3:** Rogers A, Tyler P, Connelly D, **Copley J**, James R, Larter R, Linse K, **Mills R** *et al.* (2012). The discovery of new deep-sea hydrothermal vent communities in the Southern Ocean and implications for biogeography. *PLoS Biology*, **10**: e1001234 <https://doi.org/10.1371/journal.pbio.1001234>
- 3.4:** Marsh L, **Copley J** *et al.* (2015). In hot and cold water: differential life-history traits are key to success in contrasting thermal deep-sea environments. *Journal of Animal Ecology*, **84**: 898-913 <https://doi.org/10.1111/1365-2656.12337>
- 3.5:** **Copley J**, Marsh L *et al.* (2016). Ecology and biogeography of megafauna and macrofauna at the first known deep-sea hydrothermal vents on the ultraslow-spreading Southwest Indian Ridge. *Scientific Reports*, **6**: 39158 <https://doi.org/10.1038/srep39158>
- 3.6:** Chen C, Linse K, **Copley J** & Rogers A (2015). The 'scaly-foot gastropod': a new genus and species of hydrothermal vent-endemic gastropod (Neomphalina: Peltospiridae) from the Indian Ocean. *Journal of Molluscan Studies*, **81**: 322-334 <https://doi.org/10.1093/mollus/eyv013>
- These outputs resulted from NERC grants NE/D01249X/1 (Co-Is: Mills & Copley, 2008-14, £927k); NE/F017774/1 (PI: Copley, 2009-14, £392k); NE/H012087/1 (PI: Copley, 2011-12, £29k).

4. Details of the impact

The overall relationship between our underpinning research outputs and key impact-generating activities in each area of engagement was as follows:

RELATIONSHIPS OF UNDERPINNING RESEARCH TO KEY ENGAGEMENT ACTIVITIES

(3.X = underpinning output; 5.X = source to corroborate impact)



Details of activities and impacts for each area (4.1 to 4.4) are presented below. Evidence for **reach** is provided by information about audiences for our activities. **Significance** is demonstrated by:

- results from evaluations incorporated in activities to assess achievement of engagement goals;
- recognition of our engagement activities in international awards;
- newspaper & magazine reviews of popular science book featuring our underpinning research;
- testimonials from media professionals (e.g. BBC Natural History Unit) with whom we worked;
- evidence such as audience feedback, using principles from our previous experience [5.11].

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(4.1) Documentaries and broadcasts: We worked with BBC producers to feature results from our research in documentary series broadcast since 2014 [5.1]. For example, results and deep-sea footage from our investigation of Southern Ocean hydrothermal vents and the reproductive ecology of the "Hoff" crab (underpinning outputs [3.3+3.4]) featured in *Atlantic: The Wildest Ocean on Earth*, shown on BBC Two on 06 August 2015 and reaching 2.1 million viewers on first broadcast, subsequently broadcast as *Wild Atlantic* across Europe, internationally on BBC Earth, and released on DVD, iTunes, Google Play, Amazon Prime, Netflix.

Blue Planet II (episode 2: *The Deep*; first broadcast 05 November 2017) featured footage and results from the same underpinning research [3.3+3.4]; for reach of impact, that episode was the 2nd most-viewed TV programme of 2017 in the UK, watched by 13.97 million people for its first transmission, subsequently broadcast in >30 other countries (including 80 million viewers in China), and released on DVD, iTunes, Google Play, and Netflix, with an overall global reach now estimated to approach one billion people [5.2]. The content that we provided was also specifically highlighted by the BBC in pre-publicity for the series, receiving widespread press coverage [S1], indicating significance of impact from engaging the producers of the series with our research.

Testimonials from the producers with whom we worked [5.2+5.3] provide evidence for significance of impact from our engagement with the BBC Natural History Unit, such as: *"we were able to shine a light on the newly discovered Hoff Crab and the new world of the South Sandwich Island hydrothermal vents... and to remind our audience of up to a billion people around the world just how little we still know about the deep... to do so in collaboration with Dr Copley, who is a gifted communicator as well as a scientist, meant our ability to raise awareness of fragile ocean ecosystems had as great an impact as possible"* ([5.2]; *Blue Planet II* producer Orla Doherty) and *"Our story was based on research observations documenting the extreme lengths the female Hoff crab goes to, in order to protect her eggs... It is precisely this type of 'character-led' drama that draws new audiences to TV documentaries that feature the natural world... Incorporation of such footage dramatically lifted the aspirations of the series, since a public service broadcaster couldn't possibly film these environments"* ([5.3]; *Atlantic* producer Ted Giffords). Our interaction with these media professionals also taught us how to shoot deep-sea footage during our research to meet the specific needs of documentary makers [S3], building our capability to bring our work to wider audiences through that medium for our engagement goals.

In addition to TV series, we worked with radio documentary makers to feature results from our research on biodiversity at Indian Ocean hydrothermal vents (underpinning outputs [3.5+3.6]) in *The Compass: Ocean Stories*, broadcast in November 2017 on BBC World Service, which has a global reach of 75 million [3.1], though it is not possible to track total audience across countries for a specific programme. Our research investigating hydrothermal vent environments and their biodiversity in the Cayman Trough (outputs [3.1+3.2]) provided content for *Into The Abyss* on BBC Radio 4 (July 2014), which highlighted the issue of deep-sea mining and its potential environmental impacts. We also worked with an independent film-maker to produce a short film, *Hydrothermal Vents: What Does The Future Hold?*, about our Cayman Trough research and the context of deep-sea mining, which was shortlisted as a finalist in the Emerging Film-maker category at the international *Blue Ocean Film Festival* in 2014 [3.1].

(4.2) Online engagement: We created a "Massive Open Online Course" (MOOC) about *Exploring Our Ocean* to introduce people with no prior scientific background to the exploration of deep-sea environments and their biodiversity. Our online programme was designed for public engagement with our work, and included data and results from our research at Cayman Trough hydrothermal vents [3.1+3.2]. The programme ran "live" over several weeks each year from 2014 through 2020 (a total of 14 runs), with PhD students answering questions in discussion forums as participants explored topics through course videos (including footage from our underpinning research), simple data interpretation (including data from our underpinning research), and reading (including news media coverage of our research).

Since its first run in 2014, the *Exploring Our Oceans* MOOC has had >52,000 enrolments from people in 183 countries, posting >41,000 online comments and questions [5.5]. To evaluate significance of impact for the MOOC, we included "before and after" questions to capture changes in participants' awareness of deep-sea environments and their biodiversity, and to assess other outcomes for our engagement goals of "providing cultural enrichment by supporting lifelong learning" and "raising awareness of our research insights and their context". Examples of

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participant feedback [5.4] consistent with achieving those goals include *"Might sound odd but this has changed my life and inspired me beyond anything before and I'm nudging 50!"* and *"Basically my point of view has changed. Instead of marvelling at how wonderful the deep-sea creatures are, I came to realize it is necessary that we must do our utmost to protect them"*.

In addition, an HEA-funded study of the impact of our MOOC [5.4] conducted detailed follow-up interviews with 453 participants from the initial run of *Exploring Our Oceans*, providing further evidence for significance of impacts consistent with our engagement goals: 100% of those interviewed *"learned about the results of current research"* during the MOOC, and 97% *"learned something that changed the way I view an issue"*. We also assessed the impact of the MOOC on the "ocean literacy" of participants, publishing our results and sharing our experience in a peer-reviewed paper [5.5], and our MOOC was Highly Commended in the Projects category of *The Ocean Awards 2016*, sponsored by the Blue Marine Foundation and Boat International Media to recognise impact in engagement with the ocean [5.4].

For online engagement in 2020 we also worked with the producers and presenters of *Let's Go Live!*, a YouTube series for those home-schooling children during Covid-19 lockdown, bringing our findings about the ecology of hydrothermal vent shrimp [3.2] to >5,000 households during the live show and subsequently reaching >25,000 online views in total [5.6]. Underpinning research [3.5+3.6] featured in the *Guardian Science Weekly* podcast in January 2020, distributed via platforms including Apple, Google, Spotify and SoundCloud, preventing tracking of total audiences but with listener feedback including comments such as *"science communication at its best"* [5.1]. In November 2020, underpinning research [3.3] featured in the *BBC Science Focus* podcast series *Everything you ever wanted to know about... the deep sea with Dr Jon Copley*, distributed internationally via platforms including Acast, iTunes, Stitcher, and Overcast [5.1].

(4.3) In-person engagement and "popular science" book: In total, we delivered >50 in-person engagement events about our underpinning research to a total audience of >86,000 people during the REF period, and worked with a professional event producer and presenter who featured our research in 22 further events to an additional audience of ~8,600 people. Our in-person programme targeted four specific communities of place and interest: (1) local communities in the southern UK where we are based; (2) school pupils and their families and teachers; (3) lifelong learners; and (4) users of the marine environment (recreational & professional). A full list of the events that we delivered ourselves, with audience information and feedback, is provided in [5.7].

In 2015 Copley won a NERC "Summer Of Science" grant for public engagement, which we used to deliver a session of talks at the annual British Science Festival and create exhibits for the Southampton Boat Show, "Science Uncovered" at the Natural History Museum, and NERC's "RRS *Discovery* in London" programme, featuring all our underpinning research. The 2015 events reached >28,000 people in total, and we evaluated impact using audience questionnaires for our talks and a touch-screen system for our exhibits, with results [5.8] providing evidence of raising awareness of deep-sea environments and their biodiversity, such as 84% of those polled not being previously aware that UK Overseas Territories include habitats such as hydrothermal vents.

Our subsequent in-person programme from 2016 to 2018 included major events such as the Bluedot Festival in 2016 and 2018 (audience ~1,200 people); *New Scientist Live* Main Stage 2018 (~3,000 people); "R3A at the Royal Institution" 2017 (~300 lifelong learners); and keynote talks at European Maritime Day 2017 (~800 professional users of the marine environment) and the Royal Society of Biology Education Awards 2018 (~300 school pupils & teachers).

In addition, our research on Southern Ocean hydrothermal vents and the ecology of the "Hoff" crab [3.3+3.4] featured in 22 "Deep Ocean Lab" school & family festival engagement events delivered by science presenter Greg Foot during 2017 to 2020 to a total audience of 8,600 school pupils, their family members, and teachers [5.6]. His testimonial highlights the significance of impact from incorporating material from our underpinning research: *"Both the deep-sea vent footage, and showing the actual physical Crab to the audience (albeit in perspex), brought the scientific adventure and research to life... lots of follow up questions showing significant engagement and passion for ocean science"*.

Dialogue with audiences at our events from August 2013 through 2018 informed the content and format for the "popular science" book *Ask an Ocean Explorer*, written by Copley and published by Hodder & Stoughton in 2019, featuring results from all our underpinning research and sharing our research process. The book received positive reviews in newspapers and magazines

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[5.9], with comments demonstrating our goal of raising awareness of deep-sea environments and their biodiversity, such as: "*deftly conjures the wonders of a bathynaut's world*" (*Nature*); "*an engaging book sprinkled with mind-blowing facts about the deep ocean*" (*Daily Express*); "*a new informed perspective on the wide, watery world we inhabit*" (*Coast* magazine Book Of The Month, May 2019). UK paperback sales averaged ~160 per week by the end of 2019 [5.9].

Publication of the book led to a 20-date *Ask an Ocean Explorer* national tour of talks delivered by Copley in 2019 to engage people with our underpinning research, supported by the publisher whose testimonial records "*unprecedented demand*" from literary festivals and that audiences were "*animated, better informed, and brimming with discussion on leaving his talks, resulting in great book sales*" [5.9]. Examples of feedback from event organisers and audience members [5.7] indicating achievement of our engagement goals included: "*wonderful talk on the creatures of the deep and our impact on the oceans... best questions ever from the youngsters in the audience*" and "*an amazing and inspiring talk about deep sea life and biodiversity*".

Beyond the *Ask an Ocean Explorer* tour, our programme of other in-person engagement events for 2019-2020 included Gresham College, the UK's oldest public lecture series (live audience of >300 lifelong learners and >2,800 viewers online [5.7]) and the *Monsters Of The Deep* exhibition at the National Maritime Museum in Falmouth (37,276 visitors July-December 2020 [5.7]), for which Copley was a guest curator, creating a display featuring our underpinning research on Southern Ocean hydrothermal vents and the "Hoff" crab [3.3+3.4].

(4.4) Policymaker engagement: Our goal of raising awareness of deep-sea environments and their biodiversity included engaging policymakers with results from our underpinning research, by contributing to briefings and reports on the topic of deep-sea resources [5.10], after Copley was selected for the Royal Society's Parliamentary Pairing Scheme in 2014. Results from our research on biodiversity at Indian Ocean hydrothermal vents [3.5+3.6] were described in the Parliamentary Office of Science and Technology (POST) Briefing Note on Deep-sea Mining (2015). The Royal Society's *Future Ocean Resources* report in 2017 for the Government Office for Science (GO Science), for which Mills was a Working Group Member, specifically cited [3.5] and was distributed to parliamentarians, government departments, and NGOs. Copley was also invited to present findings from this underpinning research [3.5+3.6] to the Parliamentary and Scientific Committee in 2018, and to write an article about those results for *Science In Parliament* (Autumn 2018 issue), published by the Committee to ~600 parliamentarians and civil servants.

We highlighted results from our research at Indian Ocean hydrothermal vents [3.5] in written evidence from Copley to the House of Commons Environmental Audit Committee (EAC) inquiry on Sustainable Seas in 2018, to which Mills was also invited to submit oral evidence. A key result from that underpinning research was described in the Committee's final report to government (page 32 of the report [5.10]) and mentioned specifically in discussion of the report in the House of Commons chamber on 17 January 2019 (Hansard, vol 652 col 1358 [5.10]), informing a UK policy recommendation for a moratorium on mining active hydrothermal vents. In December 2020, Copley was the UK's invited participant in the UN International Seabed Authority workshop developing an international framework for environmental management of mid-ocean ridge ecosystems.

5. Sources to corroborate the impact

5.1 Summary of media engagement with our research since 2014

5.2 Testimonial from Orla Docherty, Producer of BBC *Blue Planet II*

5.3 Testimonial from Ted Giffords, Producer of BBC *Atlantic: The Wildest Ocean on Earth*

5.4 Participant feedback and HEA-funded evaluation, Exploring Our Oceans MOOC 2014-2020

5.5 Fielding S, Copley JT & Mills RA (2019). Exploring Our Oceans: using the global classroom to develop ocean literacy. *Frontiers in Marine Science*, **6**: 340

5.6 Testimonial from Greg Foot, producer & presenter of "Deep Ocean Lab" and "Let's Go Live!"

5.7 Summary of in-person engagement events during REF2021 with audience feedback examples

5.8 Report to NERC from impact evaluation of 2015 "Summer Of Science" engagement grant

5.9 Publisher testimonial and book sales data and reviews for *Ask an Ocean Explorer* (2019)

5.10 Summary of policymaker engagement with our research since 2014

5.11 Copley J (2018). Providing evidence of "impact" from public engagement with research: a case study from the UK's Research Excellence Framework (REF). *Research For All*, **2(2)**: 230-243