

This is a repository copy of *Marine Conservation Begins at Home:How a Local Community and Protection of a Small Bay Sent Waves of Change Around the UK and Beyond*.

White Rose Research Online URL for this paper:

<https://eprints.whiterose.ac.uk/id/eprint/158673/>

Version: Published Version

Article:

Stewart, Bryce Donald orcid.org/0000-0001-5103-5041, Howarth, Leigh Michael, Wood, Howard L. et al. (6 more authors) (2020) Marine Conservation Begins at Home:How a Local Community and Protection of a Small Bay Sent Waves of Change Around the UK and Beyond. *Frontiers in Marine Science*. ISSN: 2296-7745

<https://doi.org/10.3389/fmars.2020.00076>

Reuse

This article is distributed under the terms of the Creative Commons Attribution (CC BY) licence. This licence allows you to distribute, remix, tweak, and build upon the work, even commercially, as long as you credit the authors for the original work. More information and the full terms of the licence here:

<https://creativecommons.org/licenses/>

Takedown

If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.



Marine Conservation Begins at Home: How a Local Community and Protection of a Small Bay Sent Waves of Change Around the UK and Beyond

Bryce D. Stewart^{1*†}, Leigh M. Howarth^{2†}, Howard Wood³, Kerri Whiteside⁴, William Carney⁵, Éilis Crimmins¹, Bethan C. O'Leary¹, Julie P. Hawkins¹ and Callum M. Roberts¹

OPEN ACCESS

Edited by:

Fiorenza Micheli,
Stanford University, United States

Reviewed by:

Claudia Baldwin,
University of the Sunshine Coast,
Australia
Andrew M. Fischer,
University of Tasmania, Australia

*Correspondence:

Bryce D. Stewart
bryce.beukers-stewart@york.ac.uk

[†]These authors share first authorship

Specialty section:

This article was submitted to
Marine Conservation
and Sustainability,
a section of the journal
Frontiers in Marine Science

Received: 17 April 2019

Accepted: 30 January 2020

Published: 13 February 2020

Citation:

Stewart BD, Howarth LM,
Wood H, Whiteside K, Carney W,
Crimmins É, O'Leary BC, Hawkins JP
and Roberts CM (2020) Marine
Conservation Begins at Home: How
a Local Community and Protection
of a Small Bay Sent Waves of Change
Around the UK and Beyond.
Front. Mar. Sci. 7:76.
doi: 10.3389/fmars.2020.00076

¹ Department of Environment and Geography, University of York, York, United Kingdom, ² Oceanography, Life Sciences Centre, Dalhousie University, Halifax, NS, Canada, ³ Community of Arran Seabed Trust, Lamlash, United Kingdom, ⁴ Fauna & Flora International, Cambridge, United Kingdom, ⁵ Marine Management Organisation, Newcastle upon Tyne, United Kingdom

The Firth of Clyde, on the west coast of Scotland, was once one of the most productive fishing grounds in Europe. However, successive decades of poor management and overfishing led to a dramatic loss of biodiversity and the collapse of finfish fisheries. In response, concerned local residents on the Isle of Arran, which lies in the middle of the Clyde, formed the Community of Arran Seabed Trust (COAST) in 1995. After 13 years of campaigning, a small (2.67 km²) area in Lamlash Bay became Scotland's first no-take zone (NTZ) in 2008, and only the second in the UK. Since protection, biodiversity has increased substantially, along with the size, age and density of commercially important species such as the king scallop, *Pecten maximus*, and the European lobster, *Homarus gammarus*. Arguably more important, however, is the influence the Lamlash Bay NTZ and COAST have had on UK marine protection in general. Most notably, detailed research has created a case study that clearly demonstrates the benefits of protection in an area where little such evidence is available. This case has been used repeatedly to support efforts for increased protection of UK waters to help rebuild marine ecosystems and enhance their resilience in an uncertain future. In Scotland specifically, lobbying by COAST led to the designation of a much larger marine protected area (MPA, > 250 km²) around the south of Arran, one of 30 new MPAs in the country. Evidence from Lamlash Bay has supported development of strong protection for these MPAs, seeing off lobbyist efforts to weaken management. Arran's conservation success has been recognized internationally and is inspiring greater involvement of local communities around the UK, and further afield, to take the destiny of their coastal waters into their own hands. Successful marine conservation begins at home.

Keywords: marine protected areas, marine reserve, community based conservation, ecosystem – based management, fisheries, marine biodiversity, Lamlash Bay, Isle of Arran

INTRODUCTION

Despite a recent increase in the coverage of Marine Protected Areas (MPAs), improvements in fisheries management (Worm et al., 2009), and ambitious international agreements for conservation (CBD, 2010; U.N., 2015), marine biodiversity continues to decline worldwide (WWF, 2018). The global degradation of marine ecosystems can reduce the number and quality of ecosystem goods and services they provide, negatively affecting human livelihoods and well-being (Naeem et al., 2016). Reductions in biodiversity can also leave marine ecosystems less resilient to future shocks and changes (Howarth et al., 2014). Furthermore, rapidly increasing threats from ocean warming and acidification could degrade marine ecosystems further unless there is rapid action to reduce greenhouse gas emissions (Nagelkerken and Connell, 2015).

A key reason why conservation targets have failed to protect biodiversity is that they can promote responses that focus on giving the appearance that action has been taken, rather than ensuring the action taken was effective. For example, a major driver of the recent increase in MPAs was the CBD Target 11, set in Nagoya in 2010, to ensure that *'at least 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas'* (CBD, 2010). In response, many countries rapidly designated new MPAs within their waters, without necessarily using the best available science to design them, or giving sufficient prior thought as to how they will be managed or enforced (Lubchenco and Grorud-Colvert, 2015). Many countries have also attempted to meet conservation targets by designating MPAs in remote overseas territories, as these usually receive less opposition than MPAs proposed around the mainland (Jones and De Santo, 2016).

Although some MPAs in overseas territories have considerable conservation value (O'Leary et al., 2018), these designations may occur at the expense of providing MPAs closer to home, in places where they are greatly required because of intense human activity (Jones and De Santo, 2016). For example, the UK has now protected 1.5 million km² of ocean in UK Overseas Territories (UKOTs) where fishing is completely banned, with a further 1.5 million km² under partial protection and more promised in the future (O'Leary et al., 2019). In contrast, there are only four highly protected MPAs around the British Island, out of a total of 355, which cover just 21.07 km² or 0.0024% of UK seas (July 2019: Howarth et al., 2011; Solandt, 2018; JNCC, 2019). Fewer than half of these MPAs have management plans (JNCC, 2019), and most these are unambitious, with aims to maintain degraded ecosystems in their present state (Plummeridge and Roberts, 2017). Consequently, most UK MPAs still allow fishing within their boundaries, including damaging methods such as scallop dredging and bottom trawling (JNCC, 2019).

This problem of 'paper parks,' which give the appearance of protection without actually delivering it, is a global one. In fact, a recent study of MPAs in European seas by Dureuil et al. (2018) found trawling activity and declines of elasmobranchs to be higher inside MPAs than outside, because management

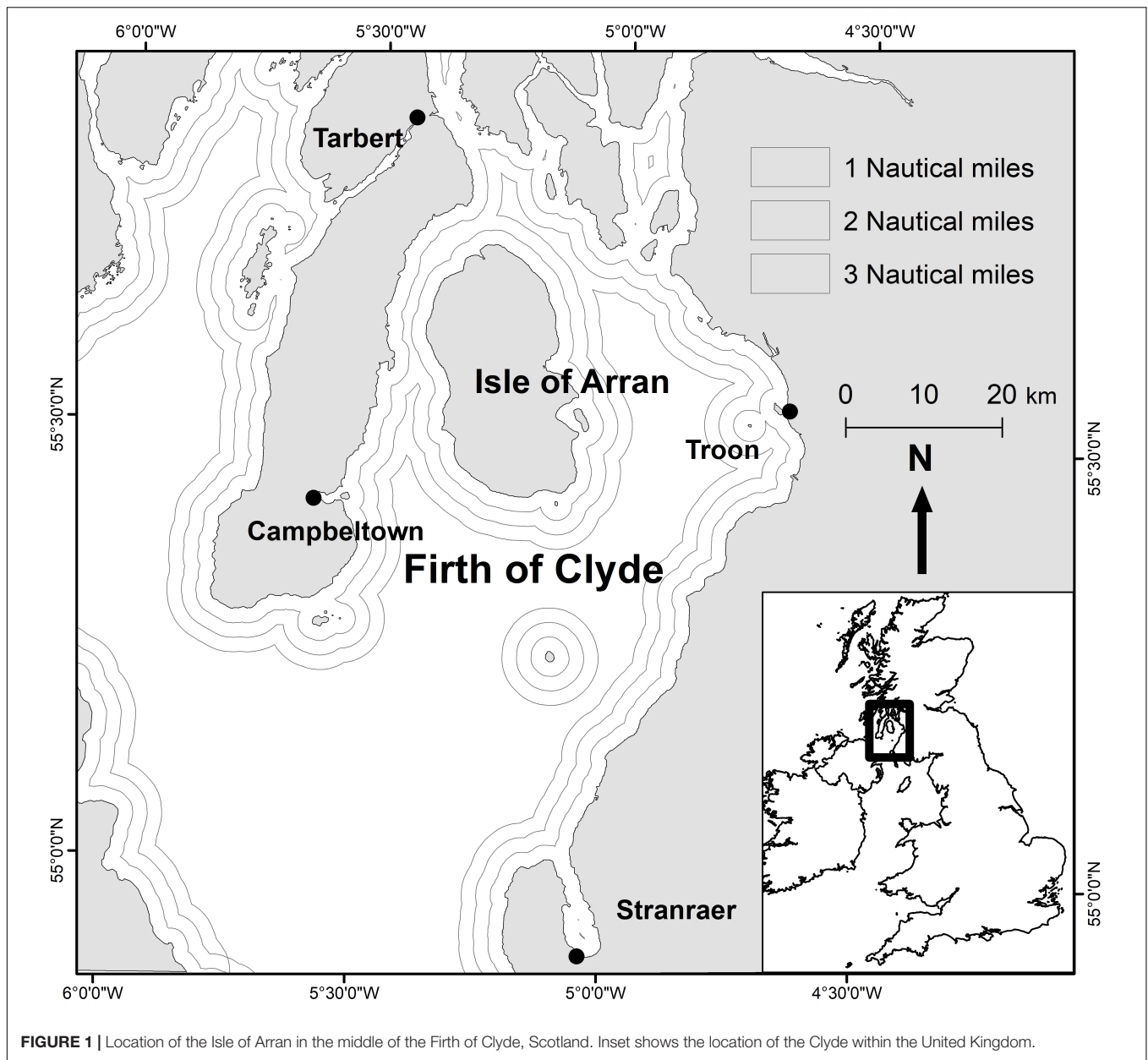
was either inappropriate or poorly enforced. 'Paper parks' are problematic because they allow authorities to claim they have taken effective action when the reality is untrue. MPAs may become paper parks if (a) they are poorly sited and/or designed, (b) management plans fail to address present and future threats to biodiversity, and (c) are poorly enforced (Rife et al., 2013). From the opposite perspective, a global review by Edgar et al. (2014) concluded that successful MPAs are: (1) no take, (2) well-enforced, (3) old (>10 years), (4) large (>100 km²), and (5) isolated by deep water or sand.

A recurring theme in the failure of MPAs is lack of stakeholder engagement (Giakoumi et al., 2018). Stakeholders commonly includes fishers, divers and other water users, but may also include concerned local residents and/or visitors. Such people can help provide valuable information about biodiversity at a site and the type and level of human activity present; information needed for effective MPA design (Gleason et al., 2010). Involvement of stakeholders also fosters a sense of stewardship in people, which helps with compliance of regulations and reduces enforcement costs (Giakoumi et al., 2018).

The involvement of stakeholders, including local communities, in MPA designation has been most common in tropical less developed countries (Jones, 2014). In these areas, MPA practitioners have often aimed to work within traditional frameworks of marine resource use and protection (Jupiter et al., 2014). In contrast, the designation of MPAs in developed countries generally follows a top-down process, initiated and controlled by government agencies or other relevant authorities (Jones, 2012, 2014). Stakeholders may be consulted as part of this process, but their overall influence on decisions is often marginal (Jones, 2012). However, in the case study presented here, we describe an exception to this trend whereby the community on Scotland's Isle of Arran changed the course of marine conservation in their local waters, and in doing so, influenced national policy and action. Here, a community identified that their local marine environment was not what it once was, diagnosed the cause and began to campaign for a solution. Arran represents an inspiring case of a tenacious community that would not give up on their local environment. The community on Arran also engaged with scientists early in the process. Science informed their campaigning, and campaign goals helped refine science needs and secure funding. The relationship has been symbiotic and is an excellent example of how science and communities can support each other to achieve the mutual goal of influencing policy to achieve better management. We hope this story will help encourage other coastal communities to take more control over the destiny of their local marine environments to turn both local and global marine conservation efforts toward a more positive direction.

THE FIRTH OF CLYDE – A TRANSFORMED ECOSYSTEM

The Isle of Arran sits in the middle of the Firth of Clyde, off the west coast of Scotland (**Figure 1**). This fjordic



inlet is approximately 100 km long and has supported diverse and highly productive fisheries for species such as herring (*Clupea harengus*), cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), turbot (*Psetta maxima*), and flounder (*Platichthys flesus*) (Thurstan and Roberts, 2010). However, a series of poor fishery management decisions caused finfish stocks in the Clyde to decline from the mid-1980s. Perhaps the most important of these was the removal of a long-standing ban on trawling by large vessels in the Clyde in 1962, followed by lifting the closure to trawling within 3 miles of shore in 1984 (Thurstan and Roberts, 2010; Heath and Speirs, 2011).

In place of finfish fishing, shellfish fisheries have grown, particularly for Dublin bay prawns (*Nephrops norvegicus*), king

scallops (*Pecten maximus*) and to a lesser extent European lobsters (*Homarus gammarus*) and brown crabs (*Cancer pagurus*) (Thurstan and Roberts, 2010). Together these shellfish species now constitute 98% of commercial landings in the Clyde and have an economic value similar to that of the previous finfish fisheries (Howarth et al., 2014). Although Dublin bay prawns and king scallops can be caught using gear that has relatively low environmental impacts (creels and SCUBA diving respectively), in the Clyde prawns are mainly targeted by otter trawls and scallops by Newhaven dredges (McIntyre et al., 2012). These bottom-towed gears can generate considerable bycatch and cause loss of diversity in benthic communities and homogenization of seabed structure (Bergmann et al., 2002; Kaiser et al., 2006; Stewart and Howarth, 2016). Such changes

to the Clyde ecosystem, particularly loss of complex habitat essential for survival of juvenile fish, and the lucrative nature of the current shellfish fisheries, are thought to be barriers to the area's restoration (Howarth et al., 2014). Furthermore, this simplified ecosystem and the fisheries it supports are likely to be at risk, both economically and ecologically, from future anthropogenic climate change and the threats it brings (Howarth et al., 2014).

Analysis of fisheries independent surveys demonstrates significant changes to fish community structure in the Clyde between 1927 and 2009 (Heath and Speirs, 2011; McIntyre et al., 2012). During this period, fish biomass changed from being distributed across a large number of species, with many individuals reaching large sizes, to being dominated (90%) by small whiting (*Merlangius merlangus*) below commercial size (Heath and Speirs, 2011; McIntyre et al., 2012). Evidence suggests that high fishing pressure, including bycatch in the current Nephrops fishery, has induced maturation to occur earlier and at smaller sizes in cod, haddock and whiting (Hunter et al., 2015). Baited Underwater Remote Video (BRUV) surveys around the Isle of Arran have also found that whiting recruited earlier, grew faster and were behaviorally dominant over other gadoid species, providing them with a competitive advantage (Elliott et al., 2018). Such evidence at least partly explains the present domination of small whiting in Arran's waters, and suggests that radical management interventions will be needed to restore the Firth of Clyde marine ecosystem to its more diverse and resilient former state.

THE STORY BEHIND THE COMMUNITY OF ARRAN SEABED TRUST (COAST)

The Campaign for Scotland's First No-Take Marine Reserve: 1989–2008

The 20th century transformation of the Clyde was not only recognized by fishermen and scientists, but also by local communities who were frustrated by the apparent lack of intervention by the Scottish government. The Isle of Arran became the focal point for these arguments after local resident and SCUBA diver, Don MacNeish, returned from a trip to New Zealand in 1989. While in New Zealand, Don visited some of the world's first marine reserves and was informed about how they were benefiting fisheries and the wider marine environment (Ballantine, 2014; Whiteside, 2018). Don returned to Arran and suggested to fellow SCUBA diver, Howard Wood that they should try to replicate the same management approach in their local waters as marine reserves were non-existent in the UK at this time.

Together, Howard and Don formed a group known as the Community of Arran Seabed Trust (COAST) in 1995. COAST began to organize meetings with local fishermen and community groups to raise awareness about the deterioration of Arran's marine ecosystem, and to search for solutions. Due to the failure of previous top-down attempts such as the Nature Conservancy

Council's 1990 proposal for a Marine Nature Reserve in Loch Sween Argyll in Scotland (Jones, 1999), Howard and Don were determined to build bottom-up, community support for their ideas. Hence, they contacted the then Scottish Office Minister Lord Lindsay to highlight the need for a marine reserve and to show that Government were failing in their duty to protect the natural environment and therefore the public good.

In 1998, during a seminal meeting with local Arran-based commercial fishermen, a community proposal to create a small, fully protected area [No-take Zone (NTZ)] in Lamlash Bay was agreed (Whiteside, 2018). The relevant documentation was presented to the Inshore Fisheries Department (in 1999) in order to:

- Make Lamlash Bay a Marine Protected Area, from which mobile fishing gear is prohibited to regenerate and enhance local fish and shellfish populations
- Establish the first No Take Zone in Scotland, to protect the maerl beds present
- Investigate the fishery benefits of a NTZ and MPA, particularly with regard to scallops.

By protecting and ultimately regenerating maerl, other seabed habitats, fish and scallop populations in Lamlash Bay, COAST's aims were to:

- Improve the local marine environment;
- Help sustain livelihoods of those dependent on fishing and tourism;
- Increase the popularity of Arran as a diving and tourist destination;
- Reverse the dramatic decline of local finfish stocks;
- Educate future generations on the need for marine conservation.

Prior to University and Government involvement, COAST began to document the species and habitats within Lamlash Bay to strengthen the evidence base for protection. Their SCUBA diving members frequently reported the presence of extensive maerl beds (*Phymatolithon calcareum*), a habitat recognized within environmental legislation as being important for biodiversity and fisheries recruitment (Hall-Spencer and Moore, 2000; Kamenos et al., 2004; JNCC, n.d.). COAST therefore used the presence of maerl as the basis of their argument for protection. However, the Scottish Government, and various fishing organizations, claimed their evidence was amateur, biased and unscientific. Hence, with the aim of improving the scientific robustness of their personal observations, eight members of COAST underwent Seasearch training¹ in the spring of 2003. By the end of the summer, COAST had conducted 21 Seasearch surveys within Lamlash Bay (Duncan, 2003). These initial surveys indicated the presence of extensive maerl beds and large abundances of juvenile scallops (Duncan, 2003).

In 2004, Scottish Water announced plans to build a sewage treatment plant adjacent to the proposed NTZ in Lamlash Bay, the effluents of which would be discharged on to the maerl beds. However, thanks to COAST's Seasearch survey reports, Scottish

¹www.seasearch.org.uk

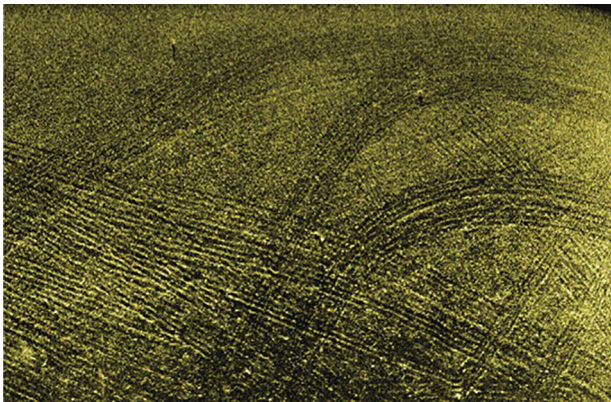


FIGURE 2 | Side-scan sonar images from within Lamlash Bay in 2004, indicating marks created by scallop dredges. Hardly any part of the seabed appears to have escaped impact.

Water were forced to commission an independent survey by The University Marine Biological Station Millport (UMBSM) to confirm the presence of maerl. These new surveys verified COAST's earlier observations and the independent report went on to state: *"In terms of the Clyde Sea, this is highly unusual and damage of that deposit may be damaging one of, if not the last > 90% live Maerl beds in the Clyde sea area. In our expert view, we would strongly advise that this site be avoided by any development which impacts on the sea bed"* (Kamenos et al., 2004). COAST used the report to engage local and national media, raising attention of both the environmental threat to the maerl bed, and to the pursuits of COAST more broadly. In response to this pressure, Scottish Water re-routed the proposed site for the sewage outfall pipe outside of Lamlash Bay. Later in 2004, COAST and UMBSM received funding from the Esmée Fairbairn Foundation to conduct side-scan sonar surveys of the bathymetry in Lamlash Bay. These surveys revealed large areas of the seabed to be covered in large, sweeping, parallel marks from scallop dredges (**Figure 2**). By combining these striking images with photos of the maerl beds and other habitats within Lamlash Bay, COAST created a powerful visual argument which could easily be communicated to the public, stakeholders and managers, for Lamlash Bay to be designated as an MPA, with an NTZ inside it.

Although much of the research conducted within Lamlash Bay between 2003 and 2006 was spatially and temporally limited, these surveys proved essential to COAST as they provided imagery and data to support their presentations, interviews, campaigns, and proposals. It helped educate the members of COAST and shaped them into a respected, well-known organization. In addition, every survey, no matter how small, attracted more attention and subsequent research.

COAST's campaign began to attract high profile national media attention (see section 'Public Outreach'), with the first significant engagement being featured in a BBC documentary 'Bee in your bonnet.' In 2004, COAST took their concerns to the heart of the Scottish Parliament through submission of a Petition

that was supported by many members of the public, marine scientists from all over the world, Members of Scottish Parliament (MSPs) representing all political parties, and many others. The Petitions Committee, after lengthy and careful consideration, passed the Petition to the Environment and Rural Development Committee of the Scottish Parliament where, after a formal enquiry in September 2006, full backing was given for COAST and the Clyde Fishermen's Association (CFA) to develop a proposal for a NTZ in Lamlash Bay. The CFA, who represented most of the mobile (prawn trawling and scallop dredging) fishermen operating in the Clyde, were initially supportive of the NTZ but became increasingly unhappy with the boundaries proposed by COAST. Despite the CFA withdrawing their support for the NTZ in early 2008, a Scottish Government consultation on the NTZ in spring 2008 received 675 responses, 99.3% of which were positive. Finally, after 13 years of campaigning and building community and scientific support, the NTZ in Lamlash Bay was designated on the 20th of September 2008. It was small (only 2.67 km² in area) but significant, being the first and still the only fully protected marine reserve in Scotland (second in the UK). Furthermore, it was unique because it was proposed and delivered through local community support, and unlike other UK MPAs, is specifically designed to provide benefits for both fisheries and conservation.

Expanding COAST, the South Arran Marine Protected Area, and Beyond: 2008 – Present

In late 2010, COAST received funding to enable them to appoint their first member of staff, Andrew Binnie, based in a rented office in Lamlash in June 2011. This, along with an assistant appointed in 2012, allowed COAST and its many volunteers to considerably raise its outreach activities and prepare a proposal for a larger MPA around the south of Arran (**Figure 3**).

Concerns raised about the degradation of the Firth of Clyde marine ecosystem by COAST and others (e.g., Thurstan and Roberts, 2010), also began to have wider impacts. In September 2010, COAST, with the help of local MSP Kenneth Gibson, met the Scottish government Cabinet-Secretary for Rural Affairs and the Environment (including fisheries) Richard Lochhead at Holyrood to voice concerns over the decline of the Clyde ecosystem. At this meeting Mr. Lochhead gave a commitment that the Scottish Government would commission their own study into the state of the Firth of Clyde.

The Clyde Ecosystem Review (McIntyre et al., 2012), largely confirmed previous findings (Thurstan and Roberts, 2010). This report was followed by the Clyde 2020 Summit, initiated by Mr. Lochhead in April 2014. This event was opened by the Minister and brought together over 100 stakeholders with interests in the Clyde, to discuss ideas for how to improve marine management. The 'trailblazing' work of COAST and the Lamlash Bay marine reserve was highlighted in his opening address (Marine Scotland, 2014). Following this event, the Clyde Marine Planning Partnership² was established in order to take forward

²www.clydemarineplan.scot/

the ideas from the Summit. In March 2019, this project released a pre-consultation draft Clyde Regional Marine Plan, designed to significantly improve the health of the Clyde marine ecosystem.

In parallel with the above specific actions in the Clyde, the Scottish government has been working to implement MPAs throughout the country under obligations from the UK Marine and Coastal Access Act 2009 and the Marine (Scotland) Act 2010. Following several years of largely government led research and an extensive consultation, 30 nature conservation MPAs were designated in Scottish waters in August 2014, perhaps the highest profile of which was the South Arran MPA. This multi-use MPA was unique because it was again proposed by COAST, to protect vulnerable seabed habitats, and covers an area just over 250 km², including Lamlash Bay (COAST, 2012; **Figure 3**).

Given the uniqueness of the Lamlash Bay NTZ as the only highly protected marine reserve in Scotland, and the availability of scientifically documented evidence of ecological recovery within the NTZ boundaries (**Figures 4, 5**, Howarth et al., 2011, 2015a,b, 2016), the NTZ played a key role in making the case for designating the South Arran MPA and other MPAs throughout Scotland (COAST, 2012). More significantly, COAST's campaigns and collaborations with scientists have been vital for ensuring the new MPAs receive adequate

protection, ensuring a lasting and far-reaching legacy. The Scottish government consulted on the management measures inside 17 of the new MPAs during 2015 (the first of two planned batches, Scottish Government, n.d.). A highly contentious issue was whether to allow trawls and scallop dredges, or only low impact creeling and diving, to continue in these areas. Research from Lamlash Bay, showing recovery of benthic biodiversity in the absence of towed fishing gear, was frequently cited in the consultation responses (Marine Scotland, 2015).

Despite considerable pressure from mobile gear fishers to allow their practice to continue in large areas of the MPAs, the Scottish government banned scallop dredging throughout the South Arran MPA in February 2016. The government agreed to only allow trawling in the outer regions, and implemented similar measures in the other 16 Scottish inshore MPAs and Special Areas of Conservation (SACs) under consideration (Scottish Government, n.d.). In addition, although creeling is allowed in much of the South Arran MPA, it was banned in several particularly sensitive seabed areas (**Figure 2**). This bold protection of the South Arran and several other inshore MPAs by the Scottish government withstood a last-minute challenge from the mobile gear fishing industry in January 2016, which was rejected by Rural Affairs and Climate Change

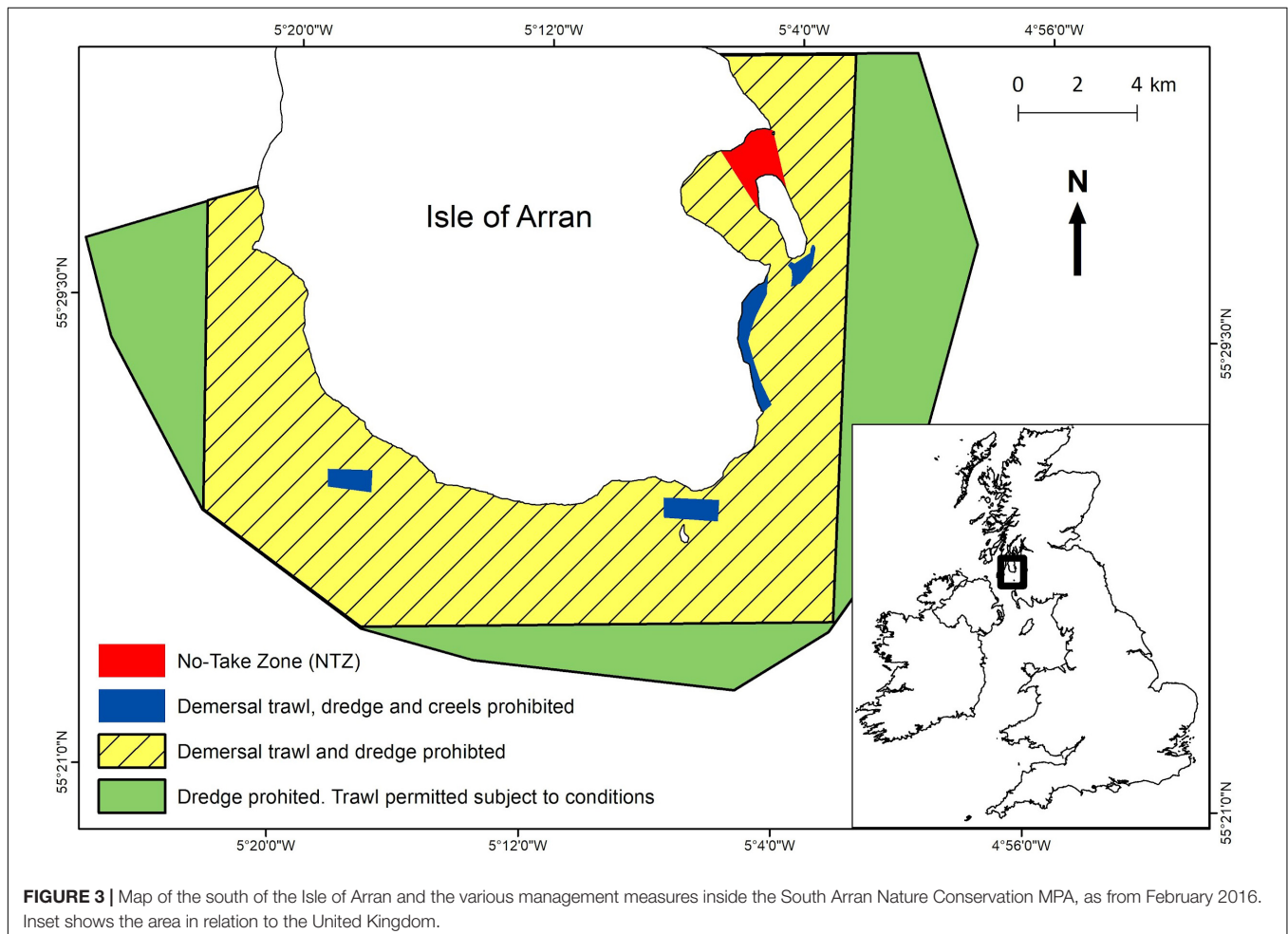




FIGURE 4 | The Story of COAST. **(A)** The three founding members at an outreach event in 2005 (Left to right: Don MacNeish, Howard Wood, Tom Vella Boyle); **(B)** COAST stall at the Arran Farmers Show, 2010 (Leigh Howarth in red coat); **(C)** Celebrating the designation of the Lamlash bay NTZ in 2008 (Left to right: Don MacNeish, Scottish Cabinet Secretary for Environment and Fisheries Richard Lochhead, Howard Wood, MSP Kenneth Gibson, Tom Vella-Boyle); **(D)** Howard Wood and Leigh Howarth doing the first SCUBA surveys of the Lamlash bay NTZ in 2010; **(E)** Surveying the South Arran MPA, 2014 (Left to right: Gus Robson, Howard Wood, Claire Youdale); **(F)** Celebrating the 10th Anniversary of the Lamlash bay NTZ at the opening of the Octopus Centre, 2018. All identifiable persons in these figures have given consent for their images to be reproduced and used publicly.

Committee (The Scottish Parliament, 2016). Although the Scottish Government (through Marine Scotland) is chiefly responsible for managing and enforcing the Arran and other Scottish MPAs (i.e., takes a top down approach), COAST continues to play an important collaborative role by advising on management measures, supporting and directing relevant science, and assisting with enforcement. For example, local residents, generally COAST members, have initially reported all of the relatively few known infringements in the NTZ and MPA around Arran, before the authorities have investigated them.

COAST's achievements in the field of marine conservation have not gone without notice. Environmental prizes to date include; the Observer Ethical Award in 2008, a place on the Scotsman Green List in 2009, the Nature of Scotland Award in 2014, the International Goldman prize for Europe and an OBE for services to the environment to Howard Wood in 2015, and the Spirit of the Community Award to COAST in 2017. The Goldman prize, considered the world's largest award honoring grassroots environmental activists³ was particularly significant.

³ www.goldmanprize.org/

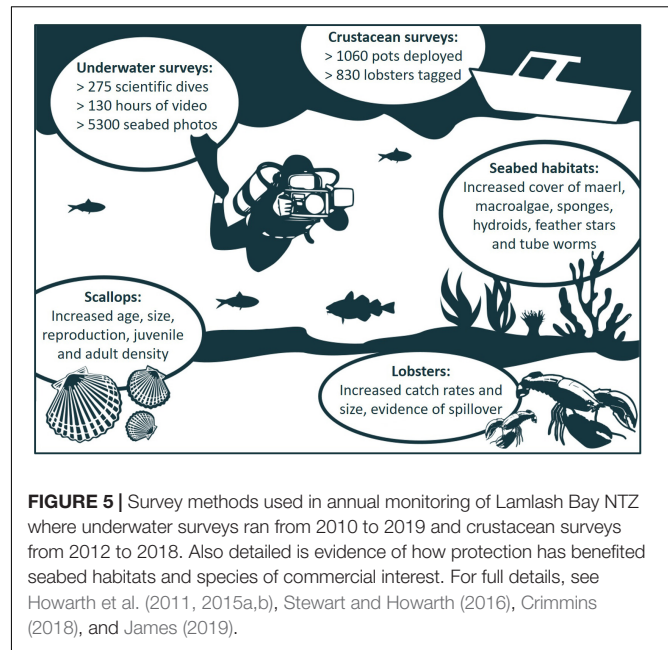


FIGURE 5 | Survey methods used in annual monitoring of Lamlash Bay NTZ where underwater surveys ran from 2010 to 2019 and crustacean surveys from 2012 to 2018. Also detailed is evidence of how protection has benefited seabed habitats and species of commercial interest. For full details, see Howarth et al. (2011, 2015a,b), Stewart and Howarth (2016), Crimmins (2018), and James (2019).

Not only did it well and truly place COAST on the international stage, the prize money allowed the purchase of land and a building on the Lamlash bay foreshore to create the 'Octopus Centre'⁴, officially opened in September 2018 to commemorate the 10th anniversary of the Lamlash bay NTZ. This is Scotland's first MPA visitor centre, and the UK's first community-led MPA visitor centre. The Octopus Centre represents a new phase in COAST's history, providing a host of marine educational material and activities designed to educate and inspire both Arran residents and the increasing numbers of national and international visitors.

THE SCIENCE BEHIND COAST'S SUCCESS

Monitoring of Lamlash Bay NTZ: 2010–Present

Routine monitoring of Lamlash Bay NTZ was initiated by the University of York in July 2010, 21 months after the NTZ was first established. These surveys were originally conducted by an MSc student and funded entirely by COAST (Howarth et al., 2011). Despite strong time and financial constraints, the project was a success thanks to substantial involvement from local volunteers and commercial fishermen operating within the area. Longer-term funding was then received from Fauna & Flora International (FFI)⁵, the Blue Marine Foundation⁶ and the Kilfinan Trust⁷, all of which enabled the project to expand into a comprehensive

⁴ www.arrancoast.com/octopuscentre

⁵ www.fauna-flora.org

⁶ www.blumarinefoundation.com

⁷ <https://bit.ly/2FFSNQB>



FIGURE 6 | Juvenile queen scallops (*Aequipecten opercularis*) have settled on and attached to this kelp frond within the Lamlash Bay NTZ. Complex three-dimensional habitats such as these are essential for the early life history survival of many marine species, including commercially valuable species such as scallops and gadoid fish. Photo: Howard Wood.

annual monitoring program using a wide variety of survey methods (**Figure 5**).

Annual photo-quadrat surveys between 2011 and 2013 revealed a variety of seabed habitats, such as sponges and macroalgae, had become more abundant within Lamlash Bay NTZ than adjacent areas (Howarth et al., 2015a). Diver transects found that the recovery of these habitats had increased the abundance of juvenile scallops by two to five times compared to neighboring fishing grounds (Howarth et al., 2015b). Structurally complex ‘nursery habitats’ such as these are used by juvenile scallops (**Figure 6**) as a refuge from predation pressure (Howarth et al., 2011; Lambert et al., 2011). Hence, the Lamlash Bay NTZ appears to be promoting the recovery of nursery habitats, which in turn, is benefiting the recruitment of a commercially important species. In the long term, these effects are likely to increase the numbers of juvenile scallops entering the adult stock as a greater proportion of juveniles survive to reach maturity (Beukers-Stewart et al., 2003; Vause et al., 2007), although further monitoring is required to fully investigate this possibility.

Despite signs that protection had increased the abundance of juvenile scallops, surveys up to 2014 did not find a significant effect of the NTZ on the density of adult scallops (Howarth et al., 2015b; Boulcott et al., 2018). This lack of an early response in adult scallop density could be due to several factors including: (1) the small size of the NTZ; (2) a reduction in fishing pressure adjacent to the NTZ (on the control sites) after the NTZ was designated; (3) high variance of density estimates due to highly aggregated scallop distributions; and (4) episodic fluctuations in recruitment (Beukers-Stewart and Beukers-Stewart, 2009; Howarth et al., 2011, 2015b; Boulcott et al., 2018). Then again, both king scallop ages and sizes were significantly larger in the NTZ than outside (with differences increasing from 2010 to 2013), indicating that the population there was returning to a more natural, unfished state (Howarth et al., 2015b). Corresponding with these differences in body size, exploitable biomass (an indicator of commercial value) and reproductive biomass (an indicator of reproductive potential) were also greater within the NTZ than outside. Even more encouragingly, the

most recent diver surveys, undertaken in July and August 2019, found that king scallop density in the NTZ has since increased dramatically, and is now more than 3.7 times higher than it was in 2013 (James, 2019). As a result, densities of adult scallops are now significantly higher in the NTZ than they are in an area still open to dredging off the NE coast of Arran (James, 2019). Overall, these findings indicate that the NTZ is protecting scallops from fishing mortality, allowing them to become more numerous, larger, older, and more fecund. This should mean the NTZ is contributing disproportionately to recruitment by exporting large amounts of eggs and larvae to surrounding areas (Beck et al., 2001; Gibb et al., 2007; Laurel et al., 2009; Harrison et al., 2012).

Annual crustacean surveys between 2012 and 2018 investigated the population dynamics of European lobster (*Homarus gammarus*), brown crab (*Cancer pagurus*) and velvet swimming crab (*Necora puber*) within the NTZ and directly outside its boundaries (Howarth et al., 2016; Crimmins, 2018). For most years, lobster catch rates were significantly higher within the NTZ, with differences being most dramatic for those above the minimum legal landing (e.g., 4.4 times higher in the NTZ than outside in 2018) (**Figure 7**). Lobster CPUE declined with increasing distance from the NTZ boundaries up to 20 km away (Howarth et al., 2016). Tagging and recapturing of the lobsters indicated this was likely due to ‘spillover’ with individuals from within the NTZ moving outside (Howarth et al., 2016; Crimmins, 2018). The body size of lobsters was also consistently greater within the NTZ across all years, and because egg production increases with body size (Cudney-Bueno et al., 2009; Harrison et al., 2012), and mature lobsters were so much more abundant in the NTZ, this difference translated to over 5.7 times more eggs within the 2.67 km² NTZ in 2018, than in an unprotected area of equal size. In combination, these results suggest that lobsters located within the NTZ are experiencing increased survivorship, allowing for establishment of higher densities, body sizes and greater reproductive output. In contrast, results for other crustacean species were more mixed. Catches of velvet crabs varied greatly from year to year with significant differences between inside and outside the NTZ for some years, but not for others. Catches of brown crab were consistently higher outside the NTZ than within. As brown crabs exhibited reverse trends to lobster, brown crabs may be being negatively affected through predation and/or competition by higher densities of large lobster within the NTZ (Howarth et al., 2016).

Research within Lamlash NTZ continues to provide invaluable evidence that temperate marine reserves can help to restore exploited stocks and the wider marine environment. Our surveys also highlight the importance of long-term monitoring to account for stochastic, annual fluctuations in abundance. They further demonstrate the importance of investigating multispecies interactions, as recovery of some species can have both positive and negative knock-on effects on others. Despite there now being over 350 MPAs in UK waters (JNCC, 2019), only one other, the Lyme Bay Marine Conservation Zone, has been studied in anything like the same detail as the Lamlash Bay NTZ (Mangi et al., 2011; Sheehan et al., 2013). Our results demonstrate that recovery of biological communities inside protected areas is not monotonic; instead, what we are seeing is complex,

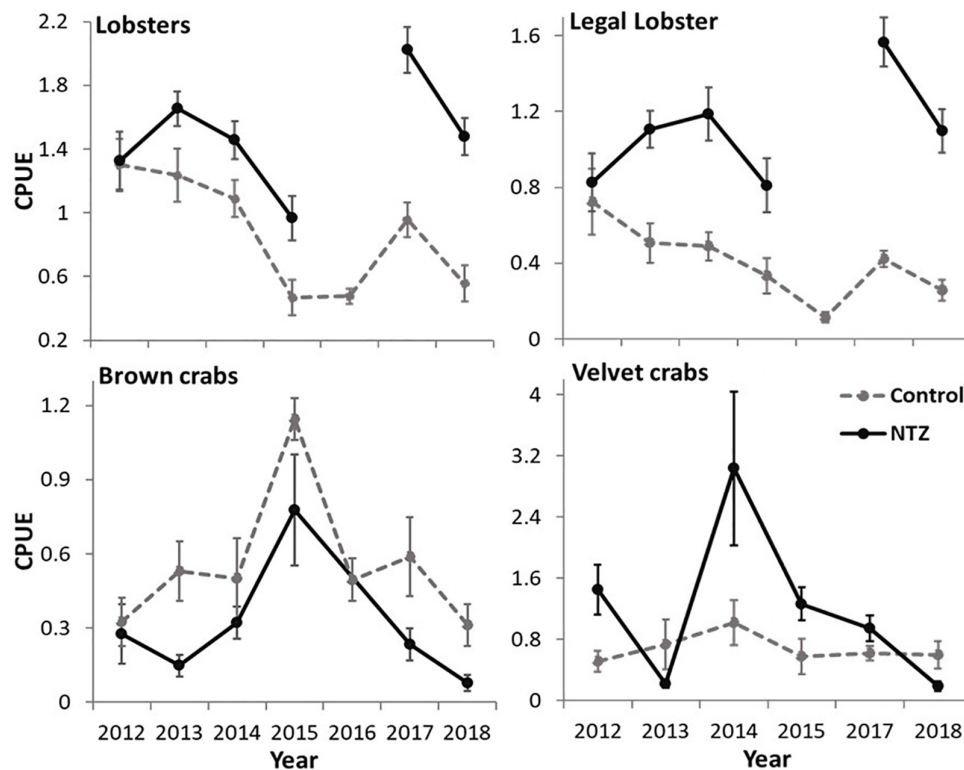


FIGURE 7 | Mean catch per unit effort CPUE (y-axis) of lobsters, legal-sized lobsters (> 88 mm carapace length), brown crab, and velvet swimming crabs within the NTZ and control sites in the surrounding fishing grounds over the 6-year study period (2012–2018). Black lines represents the NTZ and gray lines the control sites. Error bars represent ± 1 SE. There is no data for the NTZ in 2016 because it was not surveyed that year.

ecological processes unfolding in a dynamic environment. This should not be seen as problematic, the complexity should be embraced; it is a more accurate reflection of how ecosystems naturally function. This emerging understanding is crucial for both setting realistic management objectives for other MPAs in the region, and for managing the expectations of conservationists and managers in the future.

Making the Case for and Monitoring the South Arran MPA: 2011–Present

As stated earlier, COAST began building the scientific case for the larger South Arran MPA soon after the designation of the Lamlash Bay NTZ. The key first step was to identify the location and extent of ‘priority search features’ – vulnerable species and habitats recognized as such by national and international policies, such as seagrass, maerl, mussel beds, and sponge communities (COAST, 2012). Although considerable information was already available (e.g., on the seagrass beds in Whiting bay), there were known to be significant gaps in knowledge (COAST, 2012). From 2011 to 2012, COAST therefore undertook a large number of ‘search dives’ around the south of Arran, enlisting the help of local volunteers, Seasearch and University of York students. This information was then supplied to the Joint Nature Conservation Committee (JNCC), who provide UK governments with conservation advice, and validated by Scottish Natural

Heritage (Howson and Steel, 2014), and was a key component in determining the extent of the proposed South Arran MPA and ultimately its successful designation (COAST, 2012).

Given the limited amount of quantitative biological data from Lamlash bay before designation of the NTZ, COAST were keen to avoid the same situation arising in the South Arran MPA. Management measures were scheduled to be implemented in the MPA in 2016, leaving the summers of 2014 and 2015 to conduct baseline surveys. Approximately, 40 dive surveys were done throughout the MPA over those 2 years (Hutchinson, 2015; Stark, 2015) using similar methodology to previous surveys (Howarth et al., 2011), but with dive transects also being videoed to provide a permanent record against which future surveys could be compared. Early analysis of dive surveys repeated at these sites in July and August 2019 suggests dramatic recovery after only 3.5 years of protection from dredging, with densities of king scallops over sixfold higher than in the previous surveys (James, 2019).

Researchers from the University of Glasgow, in collaboration with Scottish Natural Heritage, Marine Scotland Science, and recently the University of York, have also carried out a series of studies of fish nursery habitats within the South Arran MPA. These benefit from the mosaic of different seabed types within the MPA and the reduced disturbance in later years once trawling and dredging had been restricted (David Bailey, personal communication). These studies have revealed differences in

nursery habitat use and other behaviors in the three main commercial gadoid fish species (cod, haddock, and whiting) (Elliott et al., 2017b, 2018) with evidence that cod in particular responds positively to higher benthic biodiversity and landscape heterogeneity (Elliott et al., 2017a,b). This work, which has involved over 600 camera drops at the time of this publication, provides a dataset covering the designation and protection of the wider MPA, which will allow changes to its protected features, biodiversity and ecosystem functions to be determined. The protected ground of the MPA will become an important area for the study of marine landscape ecology, a topic with great potential to improve our understanding of marine ecology and to improve management practices.

Finally, the role of the South Arran MPA for storing carbon, and hence helping to mitigate climate change, is now also being to be recognized. In a recent assessment of the contribution of Scotland's MPAs to carbon storage (Burrows et al., 2017), the South Arran MPA was assessed as providing the fifth highest contribution, with an estimated stock of total carbon (organic and inorganic forms from both biological and geological (sediment) sources) of 8,046 tons per km². Burrowed mud, which makes up a significant proportion of the South MPA (~ 160 km²) is known to be a particularly important long-term carbon store, especially when it is not disturbed by trawling or dredging (Smeaton and Austin, 2019).

BENEFITS BEYOND BOUNDARIES

COAST's influence on community-led marine protection goes well-beyond the shores of Arran. Whilst COAST's founders set out with a very specific goal – to close off and manage a small area of the sea for natural regeneration – their activities have sent waves of change around the UK and beyond.

Public Outreach

A core part of COAST's mission since its formation has been to undertake public outreach in order to educate people about both marine conservation issues and to build support for potential solutions. This has included running regular public activities on Arran (e.g., rock pool rambles for the public, school visits, stalls and displays at community events) and now hosting visitors at their Octopus Centre (over 11,000 between August 2018 and August 2019). Media engagement has also been used to build public and political support since the beginning of COAST's campaign for the Lamlash bay NTZ. One of the most important productions was the near hour long 2006 documentary about COAST called 'Caught in Time' filmed and produced by Doug Anderson, with strong Arran connections and now a renowned BBC wildlife cameraman: www.youtube.com/watch?v=fdAJK7CkNbQ&feature=youtu.be. This came at a time when their campaign appeared to be stalling, despite widespread local and scientific support. A further 25 min of live coverage on BBC News 24 in May 2007 continued to raise public awareness, the year before the NTZ was finally designated. More recent print and online highlights include the Times in July 2018 (<https://bit.ly/2U2ED6c>); the Smithsonian Institution

in January 2017 (<https://s.si.edu/2HUH8QJ>); the New York Times in August 2015 (<https://nyti.ms/2JNRft5>) and National Geographic in April 2015 (<https://bit.ly/2I52IBQ>). There has also been considerable national television coverage, most recently features on the UK's BBC – Blue Planet UK in March 2019, Countryfile in February 2019, and Springwatch in June 2018, and internationally on Al Jazeera in 2013 (<https://bit.ly/2uzSj9F>). In 2010, the Franco-German TV channel Arte also made a 10 min documentary for distribution across Europe, particularly France and Germany, but also the Netherlands, Belgium, Luxembourg, Switzerland, Austria, Italy, and Israel.

Scientific outputs from the Universities of York and Glasgow on the research done on the Lamlash Bay NTZ and South Arran MPA have also been widely promoted through the media, generally in collaboration with COAST. These have again attracted widespread national and international coverage (e.g., The Scotsman <https://bit.ly/2uABOdq> and <https://bit.ly/2FFuL8n>; Futurity <https://bit.ly/2uydp82> and <https://bit.ly/2FInqWC>), and helped promote both the Isle of Arran marine conservation success story, and the supporting scientific research.

Scientific Influence

The Universities of York and Glasgow have published 10 peer-reviewed journal articles, 1 report and 1 book chapter on the marine ecosystems around Arran and in the Clyde, since 2010. Collectively, these publications have been cited 274 times (Google Scholar 20/01/2020). This research helps fill an important knowledge gap because the recovery of marine ecosystems inside MPAs in temperate waters remains understudied (Fenberg et al., 2012). In terms of community led MPAs in temperate waters, the work is even more unique. COAST have also played an important role in nurturing young marine scientists. To date, they have hosted 24 BSc, MSc, and Ph.D. research projects from the Universities of York, Glasgow, Heriot Watt, Edinburgh Napier, and St Andrews, Bangor University, University of the West of England, and University College London. Furthermore, 17 young scientists and conservationists have traveled to Arran to work with COAST, from a diverse range of countries such as the UK, the Irish Republic, Germany, Greece, Canada, New Zealand, and South Africa.

Supporting Other Marine Conservation Campaigns

COAST's success with the Lamlash Bay NTZ not only helped support their campaign for a much larger MPA designation around the south of Arran, it has also kick-started and inspired a national movement which has empowered and united other communities and increased grassroots participation in marine management.

A significant early step was helping to form the Sustainable Inshore Fisheries Trust (SIFT www.sift-uk.org/) in 2011, with Howard Wood from COAST as a founding board member. SIFT's stated goal is '*promoting the sustainable management of Scotland's inshore waters so that they provide the maximum long term socio-economic and environmental benefits to all Scotland's coastal communities.*' SIFT therefore has a broad remit, but

its initial focus was guided by the concerns of COAST and others about the degraded state of the Clyde. Following almost 3 years of research and stakeholder engagement from 2013 to 2016, SIFT submitted an innovative spatial management plan to the Scottish Government, aimed at helping revitalize Clyde fisheries and marine ecosystems. Although not ultimately taken forward by the Scottish government, their work has kept the Scottish government focused on the plight of the Clyde and many of their ideas have been adopted by the Clyde Marine Planning Partnership (see earlier). SIFT has had more success recently, helping to run a campaign which stopped a large-scale commercial proposal by a biopolymer company to dredge for kelp in Scottish waters.

Since 2014, COAST has also been working with Fauna & Flora International (FFI), and a range of partners in Scotland, to support coastal communities in playing an active role in marine conservation. The need for this collaboration was borne from a multitude of requests being brought to COAST from other aspiring communities and individuals – keen to replicate the success of COAST and enhance the protection of their own local waters.

Local people living and working along the coasts of Scotland have a unique dependence on marine resources, a wealth of knowledge and skills, and specific aspirations for reforms within traditional marine management decisions. Through supporting local community groups in having a stronger voice in support of marine protection, COAST and FFI have supported the emergence of new community organizations such as the Community Association of Lochs and Sounds (CAOLAS⁸) based around the shores of Loch Sunart and the Sound of Mull. The partnership has also influenced the achievement of specific conservation milestones including the establishment of Scotland's first Demonstration and Research MPA in Fair Isle, the increased exclusion of bottom-towed fisheries within MPA management measures, and the formation of a community-driven, national Coastal Communities Network⁹ in Scotland. The emerging network is already larger and more influential than anticipated, involving 16 community groups at present, with strong indications that this will continue to grow. This new platform for local communities to engage in Scottish marine management has not only increased participation at the grassroots level, but it has also provided a key mechanism for government agencies such as Marine Scotland and Scottish Natural Heritage to engage more effectively with communities. This is in line with Scotland's evolving Community Empowerment agenda and more akin to the co-management frameworks that are seen in other parts of the world.

Outside of Scotland, COAST has had significant influence, delivering talks and advice across the UK, America, and Europe. The latter through participation in the annual Europarc conference¹⁰. Connections have been made with those setting up NTZs in Mauritius, and in linking together

coastal communities networks in Tanzania. Greenpeace also chose the Lamlash Bay NTZ as one of three MPAs in the world to demonstrate 'Why ocean sanctuaries are so important,' as part of their 2018 campaign for the world's largest ocean sanctuary in the Weddell Sea, now signed by almost 2.8 million people: <https://bit.ly/2HPhkCS>; www.facebook.com/greenpeaceuk/videos/10155626965768300/?v=10155626965768300.

Wider Policy Impact

Conclusively demonstrating wider policy impact is difficult because government reports and policy documents rarely reference specific case studies or scientific publications. However, we have provided strong evidence above to highlight the significance of COAST's efforts to improve marine conservation from a local to international level. At a national level, COAST have recently set up the 'MPA Management Plan Project.' This project is using marine science, law and socio-economics to produce a bottom-up model of MPA governance and management, which aims to transform policy and actions of government and regulatory bodies to establish an effective, sustainable and adaptive MPA management system. COAST will lead on and promote a culture of best practice by establishing an effective model for managing the South Arran MPA, which is shared across the Scottish MPA network and communities. The legal governance component of this project is complete and four briefing papers have been produced in partnership with Edinburgh Law School¹¹.

Unfortunately, within the UK more widely there is still a distinct lack of MPAs offering the same high level of protection provided to the Lamlash bay NTZ, or even the South Arran MPA. In fact, a recent Parliamentary enquiry by the UK's Environmental Audit Committee (House of Commons, 2017) stated that without fully protected reference areas *"the Government will be unable to establish an effective and coherent MPA network, as they will have no benchmark against which to assess the effectiveness of management measures."* The recovery of marine life inside the Lamlash Bay NTZ was highlighted by a number of witnesses at this enquiry as being a clear demonstration of what is possible with both community support and a high level of protection. The generally inadequate management of UK MPAs at present reflects global patterns, however, now is not the time to ignore the issue, rather it is the time to further study and promote the few areas of the seas which are fully protected to better inform management elsewhere.

LESSONS LEARNED AND THE FUTURE

The Lamlash Bay NTZ and South Arran MPA join a select group of MPAs that have punched well-above their weight. The others such as Leigh marine reserve in New Zealand (Ballantine, 2014), Apo Island in the Philippines (Russ and Alcala, 1999) and Las Cruces in Chile (Navarrete et al., 2010),

⁸www.caolas.org

⁹www.communitiesforseas.scot

¹⁰<https://bit.ly/2OB0Emr>

¹¹www.law.ed.ac.uk/research/research-projects/saving-our-seas-through-law

are similarly small, but have been highly influential. They also have in common that they have been passionately fought for and thoroughly studied. On Arran, the campaign for better protection of their seas was kick-started and taken forward by a small band of committed and inspirational leaders, but its success equally lies with the engagement and support from the local community (Sutton and Rudd, 2016). This was not only crucial for building the case that the seas are a public good which should be managed for the benefit of all, but it also made COAST more resilient to the dynamics and challenges of a long, at times fraught, and ongoing campaign. Approaching and building relationships with legal experts, civil servants and politicians from the local to national level was vital for understanding the legislative frameworks and political systems that their campaigns have had to negotiate. Furthermore, COAST have skilfully used the media to promote their aspirations and to build support for their cause well-beyond the shores of Arran. Finally, COAST engaged with scientists early in their campaign and built up mutually beneficial relationships. Appropriate and timely science can inform, support and guide campaigning too much greater effect than is possible in its absence. Science therefore produces a solid platform for informed campaigning, enabling campaigners to speak with authority and for their arguments to be more resistant to inevitable attacks. With this recipe of ingredients COAST were able to disrupt the *status quo* of the marine management system in Scotland that at the time was at best ambivalent, at worst resistant, to change, and in doing so inspire other local communities to take the destiny of their coastal waters into their own hands.

COAST continues to move forwards. With their Octopus Centre, they are playing a growing role in marine education and outreach, but they are also helping mentor other coastal community groups more than ever before. Management of UK seas is improving, but still has a long way to go before we will truly have an ecologically coherent network of MPAs. On the policy front, UK marine management faces further challenges due to the UK leaving the EU (Brexit; Solandt et al., 2017; Stewart and O'Leary, 2017; Stewart et al., 2019) and of course, anthropogenic ocean warming and acidification are increasingly affecting the marine ecosystems themselves. Howard Wood, one of the founders of COAST, has now become a Global Climate Action summit 'Climate Trailblazer'¹², in order to turn his hand to these even bigger issues. Nevertheless, COAST's most important message is that any environment can benefit from better protection, and that every community has the right to a better environment if they want one. If that is embraced on a global scale then we truly will see a Seachange in the management of our seas.

ETHICS STATEMENT

All field and laboratory work in this study received ethical approval from the Department of Environment and Geography,

University of York. Sampling of specimens in the No Take Zone was done under permit from Marine Scotland.

AUTHOR CONTRIBUTIONS

BS and LH jointly coordinated this effort, led the writing, and conducted much of the science. HW provided most of the information and photos about the story of COAST. KW provided information about the wider influence of COAST. WC and EC provided the data and the figure on crustaceans. JH and CR helped to supervise the research and obtain the funding. All authors assisted with the writing of the manuscript.

FUNDING

The Esmée Fairbairn Foundation contributed toward the running of COAST from 2010 to 2017 and helped to fund some of the diving and crustacean surveys. Fauna & Flora International funded much of the research led by LH from 2011 to 2014. The Kilfinan Trust funded the crustacean surveys in 2014 and 2015. The Blue Marine Foundation funded the crustacean surveys in 2018 and the diving surveys in 2019.

ACKNOWLEDGMENTS

There is a large array of people to thank for contributing to this unfolding story. For being there with the vision and commitment from the start, none of this would have been possible without the two other founding members of COAST, Don MacNeish and Tom Vella-Boyle. Likewise, the members of COAST and the numerous staff and volunteers who have worked tirelessly, often for many years, have been equally important. The two directors of COAST, Andrew Binnie, who led the proposal for the South Arran MPA, and Paul Chandler, who has overseen the opening of the Octopus Centre, also deserve special mention. Russell Cheshire, the current chair of COAST, is another long-standing supporter who has provided essential assistance with the scientific fieldwork. The support of local fishermen and boat owners, Charlie Weir, Ian Cusick, Tim James, Gavin Cameron, and Jason Coles has been crucial for running the crustacean and diving surveys since 2012. Many students from the University of York helped to collect and analyze the data reported here, particularly Tim Cross, Pascal Dubois, Lowri Evans, Daniel Steadman, Sarah Pickup, Paul Gratton, Matthew Judge, Will Hutchinson, Jenny Stark, Brian Christie, James Spilsbury, Lauren James, and William Notley. We further thank Dr. David Bailey, for providing information on the baited remote underwater video survey work done by Glasgow University. We gratefully acknowledge the generous financial support from the Esmée Fairbairn Foundation, Fauna & Flora International, the Kilfinan Trust, and the Blue Marine Foundation to both COAST and the University of York, which made the work presented here possible.

¹²www.globalclimateactionsummit.org/trailblazers/

REFERENCES

- Ballantine, B. (2014). Fifty years on: lessons from marine reserves in New Zealand and principles for a worldwide network. *Biol. Conserv.* 176, 297–307. doi: 10.1016/j.biocon.2014.01.014
- Beck, M. W., Heck, K. L., Able, K. W., Childers, D. L., Eggleston, D. B., Gillanders, B. M., et al. (2001). The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. *Bioscience* 51, 633–641.
- Bergmann, M., Wiczeorek, S. K., Moore, P. G., and Atkinson, R. J. A. (2002). Discard composition of the *Nephrops* fishery in the Clyde Sea area. *Scotland. Fish. Res.* 57, 169–183. doi: 10.1016/S0165-7836(01)00345-9
- Beukers-Stewart, B. D., and Beukers-Stewart, J. S. (2009). *Principles for the Management of Inshore Scallop Fisheries Around the United Kingdom*. North Yorkshire: University of York.
- Beukers-Stewart, B. D., Mosley, M. W. J., and Brand, A. R. (2003). Population dynamics and predictions in the Isle of Man fishery for the great scallop. *Pecten maximus* L. *ICES J. Mar. Sci.* 60, 224–242. doi: 10.1016/S1054-3139(03)00005-5
- Boulcott, P., Stirling, D., Clarke, J., and Wright, P. J. (2018). Estimating fishery effects in a marine protected area: lamash Bay. *Aquat. Conserv. Mar. Freshw. Ecosyst.* 28, 840–849. doi: 10.1002/aqc.2903
- Burrows, M. T., Hughes, D. J., Austin, W. E. N., Smeaton, C., Hicks, N., Howe, J. A., et al. (2017). *Assessment of Blue Carbon Resources in Scotland's Inshore Marine Protected Area Network*. Scottish Natural Heritage Commissioned Report No. 957. Available at: <https://www.nature.scot/snh-commissioned-report-957-assessment-blue-carbon-resources-scotlands-inshore-marine-protected-area> (accessed March 25, 2019).
- CBD (2010). *Convention on Biological Diversity. COP 10. Decision X/2.Strategic Plan for Biodiversity 2011–2020*. Available at: <https://www.cbd.int/decision/cop/?id=12268> (accessed March 25, 2019).
- COAST (2012). *Proposed Marine Protected Area South Coast of Arran, May 2012*. Lamash: COAST.
- Crimmins E. (2018). *The Influence of the Lamash Bay no-take zone, Firth of Clyde, on spatial and Temporal Variation in the Recovery of Commercially Exploited Crustaceans*. MSc Thesis North Yorkshire: University of York, 43
- Cudney-Bueno, R., Lavin, M. F., Marinone, S. G., Raimondi, P. T., and Shaw, W. W. (2009). Rapid effects of marine reserves via larval dispersal. *PLoS One* 4:e4140. doi: 10.1371/journal.pone.0004140
- Duncan, C. (2003). “Lamash Bay Seasearch 2003,” in *Interim Report by the Marine Conservation Society to Scottish Natural Heritage, December 2003* (Edinburgh: Marine Conservation Society). Available at: <http://www.seasearch.co.uk/downloads/2003>
- Dureuil, M., Boerder, K., Burnett, K. A., Froese, R., and Worm, B. (2018). Elevated trawling inside protected areas undermines conservation outcomes in a global fishing hot spot. *Science* 362, 1403–1407. doi: 10.1126/science.aau0561
- Edgar, G. J., Stuart-Smith, R. D., Willis, T. J., Kininmonth, S., Baker, S. C., Banks, S., et al. (2014). Global conservation outcomes depend on marine protected areas with five key features. *Nature* 506, 216–220. doi: 10.1038/nature13022
- Elliott, S. A., Allan, B. A., Turrell, W. R., Heath, M. R., and Bailey, D. M. (2018). Survival of the fittest: explanations for gadoid imbalance in heavily fished seas. *Aquat. Conserv. Mar. Freshw. Ecosyst.* 28, 1192–1199. doi: 10.1002/aqc.2926
- Elliott, S. A. M., Sabatino, A. D., Heath, M. R., Turrell, W. R., and Bailey, D. M. (2017a). Landscape effects on demersal fish revealed by field observations and predictive seabed modelling. *PLoS One* 12:e0189011. doi: 10.1371/journal.pone.0189011
- Elliott, S. A. M., Turrell, W. R., Heath, M. R., and Bailey, D. M. (2017b). Juvenile gadoid habitat and ontogenetic shift observations using stereo-video baited cameras. *Mar. Ecol. Prog. Ser.* 568, 123–135. doi: 10.3354/meps12068
- Fenberg, P. B., Caselle, J. E., Claudet, J., Clemence, M., Gaines, S. D., García-Charton, J. A., et al. (2012). The science of European marine reserves: status, efficacy, and future needs. *Mar. Policy* 36, 1012–1021. doi: 10.1016/j.marpol.2012.02.021
- Giakoumi, S., McGowan, J., Mills, M., Beger, M., Bustamante, R., Charles, A., et al. (2018). Revisiting “success” and “failure” of marine protected areas: a conservation scientist perspective. *Front. Mar. Sci.* 5:223. doi: 10.3389/fmars.2018.00223
- Gibb, F. M., Gibb, I. M., and Wright, P. J. (2007). Isolation of Atlantic cod (*Gadus morhua*) nursery areas. *Mar. Biol.* 151, 1185–1194. doi: 10.1007/s00227-006-0565-0
- Glason, M., McCreary, S., Miller-Henson, M., Ugoretz, J., Fox, E., Merrifield, M., et al. (2010). Science-based and stakeholder-driven marine protected area network planning: a successful case study from north central California. *Ocean Coast. Manage.* 53, 52–68. doi: 10.1016/j.ocecoaman.2009.12.001
- Hall-Spencer, J. M., Moore, P. G. (2000). Scallop dredging has profound, long-term impacts on maerl habitats. *ICES J. Mar. Sci.* 57, 1407–1415. doi: 10.1006/jmsc.2000.0918
- Harrison, H. B., Williamson, D. H., Evans, R. D., Almany, G. R., Thorrold, S. R., Russ, G. R., et al. (2012). Larval export from marine reserves and the recruitment benefit for fish and fisheries. *Curr. Biol.* 22, 1023–1028. doi: 10.1016/j.cub.2012.04.008
- Heath, M. R., and Speirs, D. C. (2011). Changes in species diversity and size composition in the Firth of Clyde demersal fish community (1927–2009). *Proc. Royal Soc. B: Biol. Sci.* 279, 543–552. doi: 10.1098/rspb.2011.1015
- House of Commons (2017). *Environment Audit Committee, Marine Protected Areas Revisited. Tenth Report of Session 2016–17*. Available at: <https://publications.parliament.uk/pa/cm201617/cmselect/cmenvaud/597/597.pdf> (accessed March 25, 2019).
- Howarth, L. M., Dubois, P., Gratton, P., Judge, M., Christie, B., Waggitt, J. J., et al. (2016). Trade-offs in marine protection: multi-species interactions within a community-led temperate marine reserve. *ICES J. Mar. Sci.* 74, 263–276. doi: 10.1093/icesjms/fsw166
- Howarth, L. M., Pickup, S. E., Evans, L. E., Cross, T. J., Hawkins, J. P., Roberts, C. M., et al. (2015a). Sessile and mobile components of a benthic ecosystem display mixed trends within a temperate marine reserve. *Mar. Environ. Res.* 107, 8–23. doi: 10.1016/j.marenvres.2015.03.009
- Howarth, L. M., Roberts, C. M., Hawkins, J. P., Steadman, D. J., and Beukers-Stewart, B. D. (2015b). Effects of ecosystem protection on scallop populations within a community-led temperate marine reserve. *Mar. Biol.* 162, 823–840. doi: 10.1007/s00227-015-2627-7
- Howarth, L. M., Roberts, C. M., Thurstan, R. H., and Stewart, B. D. (2014). The unintended consequences of simplifying the sea: making the case for complexity. *Fish. Fish.* 15, 690–711. doi: 10.1111/faf.12041
- Howarth, L. M., Wood, H. L., Turner, A. P., and Beukers-Stewart, B. D. (2011). Complex habitat boosts scallop recruitment in a fully protected marine reserve. *Mar. Biol.* 158, 1767–1780. doi: 10.1007/s00227-011-1690-y
- Howson, C., and Steel, L. (2014). “Validation of seabed habitat MPA search feature records relating to the South Arran Nature Conservation MPA,” in *Scottish Natural Heritage. Commissioned Report No. 620*, (Inverness: Scottish Natural Heritage).
- Hunter, A., Speirs, D. C., and Heath, M. R. (2015). Fishery-induced changes to age and length dependent maturation schedules of three demersal fish species in the Firth of Clyde. *Fish. Res.* 170, 14–23. doi: 10.1016/j.fishres.2015.05.004
- Hutchinson, W. (2015). *Don't take the “P” out of MPAs: Identifying Conservation Priorities for the South Arran Marine Protected Area*. MSc Thesis, University of York, North Yorkshire, 41.
- James L. (2019). *The recovery of the commercially valuable scallop species, Pecten maximus, Under Different Forms of Protection Around the Isle of Arran*. MSc Thesis, University of York, North Yorkshire, 54.
- JNCC (2019). *UK Marine Protected Area Network Statistics*. Available at: <https://jncc.gov.uk/our-work/uk-marine-protected-area-network-statistics/> (accessed March 25, 2019).
- JNCC (n.d.). *Maerl Beds*. Available at: <http://archive.jncc.gov.uk/default.aspx?page=6023> (accessed 5 February, 2020).
- Jones, P. J. (1999). Marine nature reserves in Britain: past lessons, current status and future issues. *Mar. Policy* 23, 375–396. doi: 10.1016/S0308-597X(98)00056-6
- Jones, P. J. (2012). Marine protected areas in the UK: challenges in combining top-down and bottom-up approaches to governance. *Environ. Conserv.* 39, 248–258. doi: 10.1017/S0376892912000136
- Jones, P. J. (2014). *Governing Marine Protected Areas: Resilience Through Diversity*. Abingdon: Routledge.
- Jones, P. J., and De Santo, E. M. (2016). Viewpoint—Is the race for remote, very large marine protected areas (VLMPPAs) taking us down the wrong track? *Mar. Policy* 73, 231–234. doi: 10.1016/j.marpol.2016.08.015

- Jupiter, S. D., Cohen, P. J., Weeks, R., Tawake, A., and Govan, H. (2014). Locally-managed marine areas: multiple objectives and diverse strategies. *Pacific Conserv. Biol.* 20, 165–179. doi: 10.1071/pci140165
- Kaiser, M., Clarke, K., Hinz, H., Austen, M., Somerfield, P., and Karakassis, I. (2006). Global analysis of response and recovery of benthic biota to fishing. *Mar. Ecol. Prog. Ser.* 311, 1–14. doi: 10.3354/meps311001
- Kamenos, N. A., Moore, P. G., and Hall-Spencer, J. M. (2004). Nursery-area function of maerl grounds for juvenile queen scallops *Aequipecten opercularis* and other invertebrates. *Mar. Ecol. Prog. Ser.* 274, 183–189. doi: 10.3354/meps274183
- Lambert, G. I., Jennings, S., Kaiser, M. J., Hinz, H., and Hiddink, J. G. (2011). Quantification and prediction of the impact of fishing on epifaunal communities. *Mar. Ecol. Prog. Ser.* 430, 71–86. doi: 10.3354/meps09112
- Laurel, B. J., Ryer, C. H., Knott, B., and Stoner, A. W. (2009). Temporal and ontogenetic shifts in habitat use of juvenile Pacific cod (*Gadus macrocephalus*). *J. Exp. Mar. Bio. Ecol.* 377, 28–35. doi: 10.1016/j.jembe.2009.06.010
- Lubchenko, J., and Grorud-Colvert, K. (2015). Making waves: the science and politics of ocean protection. *Science* 350, 382–383. doi: 10.1126/science.aad5443
- Mangi, S. C., Gall, S. C., Hattam, C., Rees, S., and Rodwell, L. D. (2011). “Lyme Bay—a case-study: measuring recovery of benthic species; assessing potential ‘spillover’ effects and socio-economic changes; 2 years after the closure. Assessing the socioeconomic impacts resulting from the closure restrictions in Lyme Bay. Final report,” in *Report to the Department of Environment, Food and Rural Affairs from the University of Plymouth*, (Plymouth: University of Plymouth Enterprise Ltd).
- Marine Scotland (2014). *Clyde 2020 Summit (April 2014): Report of the Summit*. Available at: <http://www.gov.scot/Resource/0045/00453873.pdf> (accessed March 25, 2019).
- Marine Scotland (2015). *2014 Consultation on the Management of Inshore Special Areas of Conservation and Marine Protected Areas – Responses*. Available at: <https://www2.gov.scot/Publications/2015/06/3641> (accessed March 25, 2019).
- McIntyre, F., Fernandes, P. G., and Turrell, W. R. (2012). *Clyde ecosystem review. Scottish Government, Scottish Marine and Freshwater Science Report Volume 3, Number 3*. Available at: <https://www.clydemarineplan.scot/wp-content/uploads/2016/06/Clyde-Ecosystem-Review.pdf> (accessed March 25, 2019).
- Naeem, S., Chazdon, R., Duffy, J. E., Prager, C., and Worm, B. (2016). Biodiversity and human well-being: an essential link for sustainable development. *Proc. Royal Soc. B: Biol. Sci.* 283:20162091. doi: 10.1098/rspb.2016.2091
- Nagelkerken, I., and Connell, S. D. (2015). Global alteration of ocean ecosystem functioning due to increasing human CO₂ emissions. *P. Natl. Acad. Sci.* 112, 13272–13277. doi: 10.1073/pnas.1510856112
- Navarrete, S. A., Gelcich, S., and Castilla, J. C. (2010). Long-term monitoring of coastal ecosystems at las cruces, Chile: defining baselines to build ecological literacy in a world of change. *Rev. Chil. Hist. Nat.* 83, 143–157. doi: 10.4067/S0716-078X2010000100008
- O’Leary, B. C., Ban, N. C., Fernandez, M., Friedlander, A. M., García-Borboroglu, P., Golbuu, Y., et al. (2018). Addressing criticisms of large-scale marine protected areas. *BioScience* 68, 359–370. doi: 10.1093/biosci/biy021
- O’Leary, B. C., Fieldhouse, P., McClean, C., Ford, A. E. S., Burns, P., Hawkins, J. P., et al. (2019). Evidence gaps and biodiversity threats facing the marine environment of the United Kingdom’s Overseas Territories. *Biodivers. Conserv.* 28, 363–383. doi: 10.1007/s10531-018-1660-5
- Plummeridge, A. A., and Roberts, C. M. (2017). Conservation targets in marine protected area management suffer from shifting baseline syndrome: a case study on the Dogger Bank. *Mar. Pollut. Bull.* 116, 395–404. doi: 10.1016/j.marpolbul.2017.01.012
- Rife, A. N., Erisman, B., Sanchez, A., and Aburto-Oropeza, O. (2013). When good intentions are not enough... Insights on networks of “paper park” marine protected areas. *Conserv. Lett.* 6, 200–212. doi: 10.1111/j.1755-263X.2012.00303.x
- Russ, G. R., and Alcala, A. C. (1999). Management histories of Sumilon and Apo Marine Reserves, Philippines, and their influence on national marine resource policy. *Coral Reefs* 18, 307–319. doi: 10.1007/s003380050203
- Scottish Government (n.d.). *Marine Protected Areas (MPAs)*. Available at: <https://www2.gov.scot/Topics/marine/marine-environment/mpanetwork> (accessed 5 February, 2020).
- Sheehan, E. V., Stevens, T. F., Gall, S. C., Cousens, S. L., and Attrill, M. J. (2013). Recovery of a temperate reef assemblage in a marine protected area following the exclusion of towed demersal fishing. *PloS One* 8:e83883. doi: 10.1371/journal.pone.0083883
- Smeaton, C., and Austin, W. E. N. (2019). Where’s the Carbon: Exploring the Spatial Heterogeneity of Sedimentary Carbon in Mid-Latitude Fjords. *Front. Earth Sci.* 7:269. doi: 10.3389/feart.2019.00269
- Solandt, J. L. (2018). A stocktake of England’s MPA network – taking a global perspective approach. *Biodiversity* 19, 34–41. doi: 10.1080/14888386.2018.1464950
- Solandt, J. L., Stewart, B. D., and Puritz, A. (2017). *Perspective: What does Brexit mean for UK MPAs? MPA News, April 18th, 2017*. Available at: <https://mpanews.openchannels.org/news/mpa-news/perspective-what-does-brexit-mean-uk-mpas> (accessed 25 March, 2019).
- Stark, J. (2015). *South Arran Marine Protected Area: A baseline study*. MSc Thesis, University of York, North Yorkshire, 54.
- Stewart, B. D., Burns, C., Hejnowicz, A. P., Gravey, V., O’Leary, B. C., Hicks, K., et al. (2019). Making Brexit work for the environment and livelihoods: delivering a stakeholder informed vision for agriculture and fisheries. *People Nat.* 1, 442–456. doi: 10.1002/pan3.10054
- Stewart, B. D., and O’Leary, B. M. (2017). *Post-Brexit Policy in the UK: A New Dawn? Fisheries, Seafood and the Marine Environment*. North Yorkshire: University of York. Available at: <https://www.york.ac.uk/media/yes/yesoldwebsite/researchoutputs/Brexit%20Fisheries%20Brief.pdf> (accessed 25 March, 2019).
- Stewart, B. D., and Howarth, L. M. (2016). “Quantifying and managing the ecosystem effects of scallop dredge fisheries,” in *Developments in Aquaculture and Fisheries Science*, Vol. 40, eds S. E. Shumway and G. Jay Parsons (Amsterdam: Elsevier), 585–609. doi: 10.1016/b978-0-444-62710-0.00018-3
- Sutton, A. M., and Rudd, M. A. (2016). Factors influencing community fishers’ leadership engagement in international small-scale fisheries. *Front. Mar. Sci.* 3:116. doi: 10.3389/fmars.2016.00116
- The Scottish Parliament (2016). *Rural Affairs, Climate Change and Environment Committee, 3rd Meeting 2016, Session 4. Official Report*. Available at: <http://www.parliament.scot/parliamentarybusiness/report.aspx?r=10339&mode=pdf> (accessed March 25, 2019).
- Thurstan, R. H., and Roberts, C. M. (2010). Ecological meltdown in the Firth of Clyde, Scotland: two centuries of change in a coastal marine ecosystem. *PloS One* 5:e11767. doi: 10.1371/journal.pone.0011767
- U.N. (2015). *United Nations Sustainable Development Goals, 14: Life Below Water*. Available at: <https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-14-life-below-water.html> (accessed 25 March, 2019).
- Vause, B. J., Beukers-Stewart, B. D., and Brand, A. R. (2007). Fluctuations and forecasts in the fishery for queen scallops (*Aequipecten opercularis*) around the Isle of Man. *ICES J. Mar. Sci.* 64, 1124–1135. doi: 10.1093/icesjms/fsm089
- Whiteside, K. (2018). *Lamlash Bay No-take Zone: a Community Designation*. Available at: <https://ffi.maps.arcgis.com/apps/Cascade/index.html?appid=70448e12ec3c45139beca33dfc990b7a> (accessed March 25, 2019).
- Worm, B., Hilborn, R., Baum, J. K., Branch, T. A., Collie, J. S., Costello, C., et al. (2009). Rebuilding global fisheries. *Science* 325, 578–585. doi: 10.1126/science.1173146
- WWF (2018). “Living Planet Report - 2018,” in *Aiming Higher*, eds M. Grooten, and R. E. A. Almond, (Gland: WWF).

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Copyright © 2020 Stewart, Howarth, Wood, Whiteside, Carney, Crimmins, O’Leary, Hawkins and Roberts. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.