Institution: University of the Highlands and Islands (UHI)
Unit of Assessment: 7
1. Unit context and structure, research and impact strategy

Context and Structure

UHI is based in the unique marine, terrestrial and freshwater environments of the Highlands and Islands of Scotland. We undertake fundamental and applied science with much of our work addressing environmental impacts on humans and their use of the environment. Our work has global reach with our activities addressing international, national and regional priorities.

UHI's environmental science research activity is delivered and supported through the *Marine, Environmental Science and Engineering* "MESE" research cluster (that sits within UHI's management framework for Research and Knowledge Exchange (see UHI's Institutional Environment Statement, **IES**, section 1). Five of UHI's thirteen partners contribute to UoA7 relevant research: The Scottish Association for Marine Science (SAMS), the Environmental Research Institute (ERI) of North Highland College, NAFC Marine Centre (NAFC) and the Rivers and Lochs Institute (RLI) of Inverness College (IC). One staff member is based at the Agronomy Institute (AI) of Orkney College (OC), Figure 1.

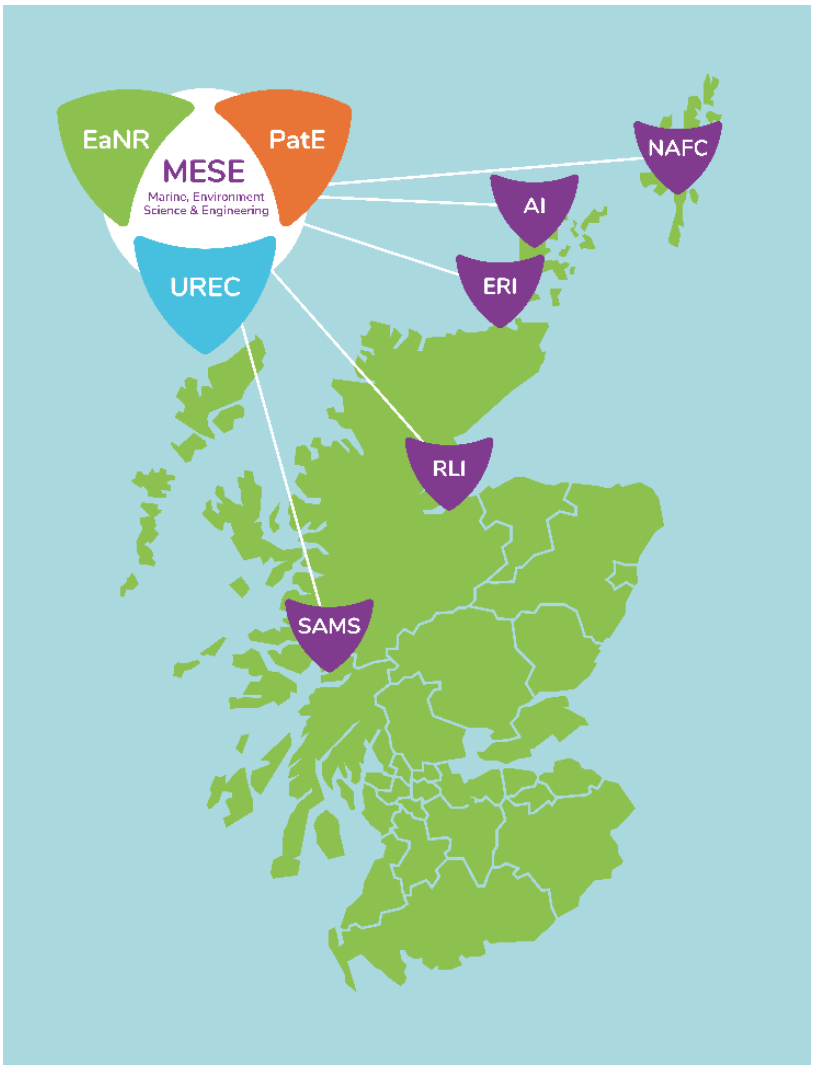

Figure 1: Geographical location of UHI partners that contribute to UoA7.

The dispersed location of the partners across the Highlands and Islands confers substantial benefits in terms of access to important research sites and associated infrastructure and allows effective engagement with regional, national, and international scientific and economic strategies.

This Research Environment Statement reflects the growth and achievements of environmental science within UHI since REF 2014 through our academic outputs, the expansion of our submission to include NAFC and OC, the increased vitality, inter-disciplinarily and sustainability generated by the establishment of MESE, the increasing international reach of our research activities, the development of our impact and enterprise activities, and the enhancement of our research facilities and support structures for staff and research students.

Achievement of strategic aim

Our mission is to undertake cutting-edge interdisciplinary marine, terrestrial, and freshwater environmental science research delivering knowledge and its practical application to meet the needs of society and business in Scotland and globally, in line with UHI's Research and Knowledge Exchange Strategy (**IES** section 2).

We employ scientists with expertise across physics, biology, chemistry, geology, modelling and technology. Staff are aligned with one or more of our three interdisciplinary environmental science themes:

- ***Understanding and Responding to Environmental Change (UREC)***
- ***People and the Environment (PatE)***
- ***Energy and Natural Resources (EaNR)***

These science themes were presented at REF 2014, with the exception that "Energy from Natural Resources" that has been retitled as "Energy and Natural Resources" to better reflect our breadth of activity. The foci of research and impact for each partner across these three themes are determined by their particular expertise (Figure 2).

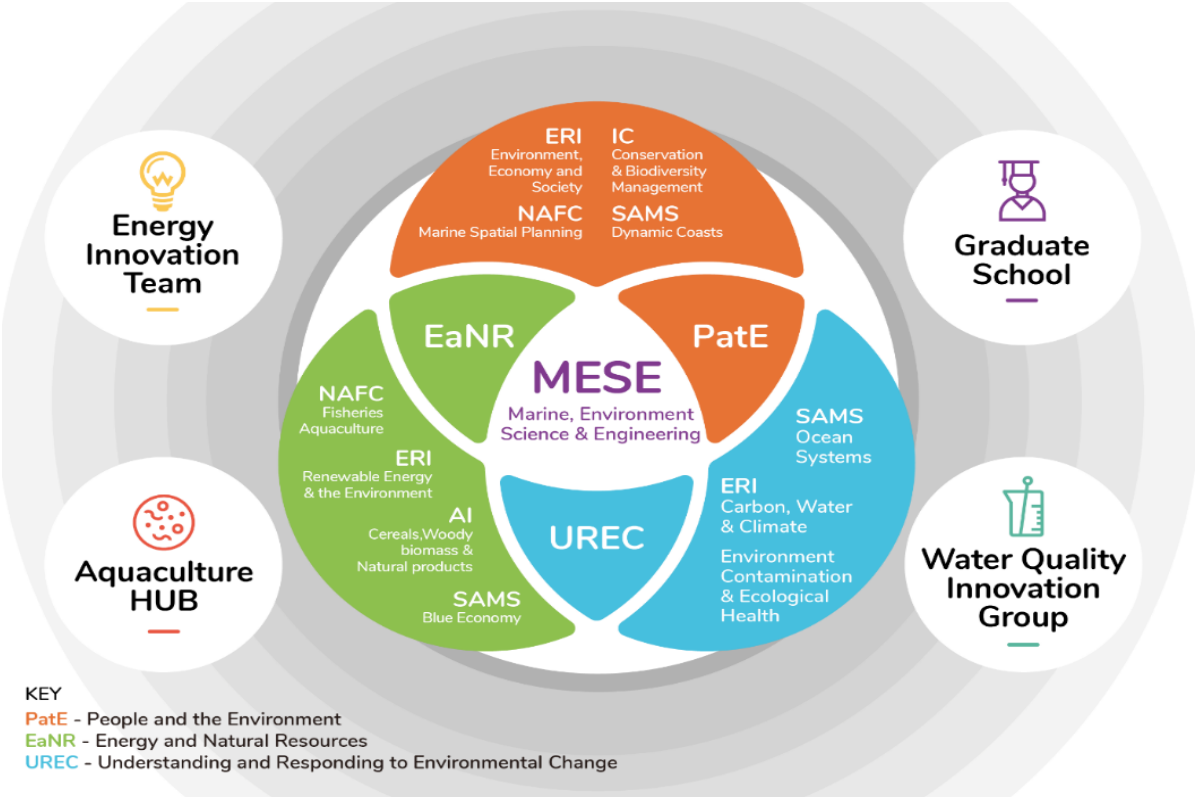

Figure 2: MESE's environmental science research and its relationship with UHI structures.

The translation of our research into impact is supported though significant investment in three sectorial knowledge exchange (KE) groups (**IES** section 2). These are the **Energy Innovation Team**, the **Aquaculture Hub** and the **Water Quality Innovation Group**. Impact is also underpinned by the research translational activity of **enterprise (commercial) arms** of each academic partner. Continued investment in KE and enterprise activity over the next REF period (**IES,** section 2) will enhance translation of research into impact.

Our graduate students are supported by UHI's **Graduate School** (**IES** section 3) and at academic partner level (Section 2 below).

Significant developments of our infrastructure and research support that have enhanced the vitality and sustainability of our research and impact since 2014 include:

- Opening of the "Bryden Centre" for Cross-border (Scotland/Ireland) Renewable Energy (2018)
- Opening of our micro-plastic research laboratory (2018)
- Development of the UK's first Shellfish Hatchery (2017)
- Establishment of UHI's core KE team and sectorial groups (2017)
- Establishment of the MESE Research Cluster (2015)
- Establishment of the NERC-funded Scottish Marine Robotics Facility - ScotMRF (2015)
- The UK National Culture Collection of Algae and Protozoa (CCAP) obtaining full economic support as a NERC Facility (2015)
- Development of the UK's largest experimental seaweed farm and hatchery (2015)
- New facilities for freshwater research including establishment of our molecular genomics laboratory (2015)

Below we outline the objectives that we set in our 2014 REF submission. We describe our relevant research (exemplified by key research papers), alongside the relevant impact and enterprise activity undertaken to meet these objectives. Where relevant, we highlight the link to our Impact Case Studies that demonstrate our approach of applying research for environmental and societal good:

***Understanding and Responding to Environmental Change,* UREC:**

Objective 1: *Increase our understanding of the marine system and its response to environmental change, including in the context of climate variability.*

Through participation in the Overturning in the Sub-Polar North Atlantic Programme (OSNAP) [Cunningham] that is using innovative ocean observing and modelling to characterise oceanographic circulation and fluxes we demonstrated [Lozier et al. 2019 Science] that circulation and water mass modifications of the North Atlantic Subpolar Gyre are fundamental to understanding of the functioning of the Atlantic meridional overturning circulation and its role in climate regulation.

Via the NERC-funded Climate Linked Atlantic Sector Science (CLASS) project that has provided ten-year funding of ScotMRF and five years for the North Atlantic "Ellett Line" sea-glider array [Inall, Cunningham] we are generating understanding that allows society to make evidence-based decisions on ocean management [Marsh et al. 2017 Ocean Science].

We have demonstrated [Burrows] the role of climate in influencing marine biodiversity [Burrows et al. 2014 Nature; García Molinos et al. 2016 Nature Climate Change; García Molinos et al. 2017 Scientific Reports]. This work has impacted policy through its presentation at the 2018 UN Climate Change Conference (COP 24), and to the Scottish Parliament's Environment, Climate Change and Land Reform Committee.

We led [Verspoor] a NERC-funded international initiative that mapped the genomic architecture of domestication in Atlantic salmon [Gilbey et al. 2016. PloS 1]. Application of this work is allowing better salmon conservation and management.

Objective 2*: Further our understanding of terrestrial and marine carbon storage and freshwater transport in terms of climate change*.

Zubkov's research is changing paradigms in oceanic carbon cycling [Zubkov 2014 Nature Communications, Zubkov et al. 2015 Nature Communications; Zubkov et al. 2018 PloS Biology] and has demonstrated the role of micro-algal dark fermentation as an important energy-conserving pathway in permeable sediments [Bourke et al. 2017 Nature Geoscience].

Research on peatlands and carbon [Andersen] [Nwaishi et al. 2015 Ecological Engineering] has informed the Scottish Government Rural and Environment Science Analytical Science programme by providing underpinning evidence on the climate benefits of peatland restoration.

We have advised [Andersen] on Scotland's National Peatland plan, with our research being used in the International Union for the Conservation of Nature Peatland Programme reports on forestry, peatlands and biodiversity and integrated in ClimateXChange policy briefs.

We have provided reports [Burrows] to advise government on Scotland's blue carbon reserves [Burrows et al. 2014, 2017]. Through the NERC Shelf Seas Biogeochemistry programme [Davidson, Hatton] we advised UK government on shelf sea carbon transport and storage [https://www.uk-ssb.org/shelf_seas_report.html].

Objective 3: *Enhance our understanding of physical, chemical, biological, and socio-economic aspects of Arctic marine systems.*

We lead [Cottier, Pond] two of NERC's Changing Arctic Ocean consortia: Arctic PRIZE (£1.5M), DIAPOD (£700K) that are quantifying the impacts of climate change on Arctic ecosystems.

Our research [Last, Cottier] has discovered active ecosystems in the polar night and their relation to ice and natural cycles of illumination [Berge et al. 2015 Current Biology; Last et al. 2017 Current Biology].

We have determined the mechanisms for tidewater glacier calving [Inall, Cottier] which impacts on sea-level rise [Luckman et al. 2015 Nature Communications], and [Inall] that climate driven changes in Arctic water can influence lower latitude circulation [Holt et al. 2019 Geophysical Research Letters].

Brown's research has used novel organic biomarkers for paleo Arctic sea ice reconstructions [Brown et al. 2014 Nature Communications].

We have related our findings to policy through provision of advice to UK and Scottish Governments on their respective Arctic strategies and policies [Cottier, Inall] leading to the publication of Scotland's first Arctic Policy Framework.

***People and the Environment,* PatE:**

Objective 1: *Develop new methods to manage the marine environment that effectively includes local people, communities, and users.*

Development and commercial launch of the NewDEPOMOD modelling tool [Black et al.] that predicts the impact of fish farm discharges allowing the global finfish aquaculture industry to meet regulatory requirements [Adams et al. 2020 Aquaculture Environment Interactions, **Case Study 1**].

Fox's work has allowed Scottish Government and DEFRA to meet the requirements of the EC fishing discards ban with respect to Nephrops [Fox et al. 2020 ICES J. Marine Science, **Case Study 4**].

Objective 2: *Develop new methods that apply the ecosystem-based management approach to real-life situations where environmental, socio-cultural, and economic considerations exist.*

Our research has been central to governmental aquaculture policy development, as highlighted by our leadership [Tett] of the Review of the Environmental Impacts of Salmon Farming in Scotland for Scottish Government in 2018.

We [Black, Tett] led the 22 partner EU-funded Aquaspace consortium that developed tools to mitigate spatial and socio-economic constraints on aquaculture [Billing et al. 2018 Ocean Coast Management].

Objective 3*: Understand how environmental contaminants impact human and ecological health.*

We [Bond] have demonstrated the accumulation of plastic debris on a previously pristine island [Lavers et al. 2017 PNAS] and [Narayanaswamy] in deep-sea environments [Woodall et al. 2014 Royal Soc. Open Science; Courtene-Jones et al. 2019 Environmental Pollution].

Our explanation [Bond, Taggart] of the role of contaminants in affecting the health of seabirds [Bond et al. 2015 Proc. Royal Soc. B] and Asian vultures [Cuthbert et al. 2016 Oryx] has allowed mitigation actions to be developed by the UN Environment Programme **[Case Study 3].**

Objective 4: *Contribute to ecosystem-based management of natural resources, study the links and feedbacks that drive coupled social-ecological systems and underpin good marine and environmental governance.*

The development [Shucksmith] of Scotland's first regional marine plan in the Shetland Islands [Kelly et al. 2014 Ocean and Coastal Management] has informed the development of Marine Spatial Plans in regions including Europe, Asia, and North/Central America.

We [Hughes] are developing and exchanging knowledge on best practice within the field of Multi-Trophic Aquaculture [Alexander and Hughes 2017 Aquaculture].

Objective 5: *Enhance our understanding of physical, chemical, biological, and socio-economic aspects of Arctic marine systems (intersecting with UREC).*

We provide UK representation on the International Arctic Science Committee Marine Working Group, participated in the UK All Party Parliamentary Group for Polar Regions [Cottier] and provided evidence [Inall] at the Westminster Environmental Audit Committee enquiry into "The Changing Arctic".

We lead the Circular Ocean Northern Periphery and Arctic programme that is developing innovative and sustainable approaches towards the processing, recycling, and repurposing of marine plastic waste in the Arctic *http://www.circularocean.eu/*

We lead the HUGE programme that is evaluating hydrogen utilisation as a means of providing energy security in Arctic regions (linking with EaNR) *https://huge-project.eu/*

Objective 1: *Underpin sustainable development of the renewable energy sector and strengthen links with Government and stakeholders in offshore wind, wave and tidal-stream industries.*

Resulting from the €4M MERIKA project that sought to achieve impact through R&D collaboration we have developed a European research and innovation hub in marine energy [Wilson] that has developed a deeper environmental, social and economic understanding of issues related to marine renewable energy. The legacy of this is the "Bryden Centre" Cross-border Renewable Energy Centre with Queen's University Belfast (**IES** section 2).

We [Wilding] have demonstrated the association between benthic species, commercial fishing intensification and subsea pipelines [Rouse et al. 2017 ICES J. Marine Science]. These results have informed the national Marine Plan Interactive tool and are routinely used by operators and Marine Scotland Science (MSS) in oil-rig decommissioning planning and have formed part of an international review on pipeline decommissioning practices conducted by BEIS for OSPAR.

Our [Howe] contribution to the NERC Maritime Environmental Mapping Programme that integrated multi-partner sea floor mapping research activity is informing practical applications such as marine planning, conservation and industrial development [Boswarva et al. 2018 Continental Shelf Research].

Riche and Williamson's research has developed methods for acoustic monitoring of marine renewable energy devices and evaluated the implications of tidal turbine noise for marine mammal collision risk [Williamson et al. 2016 IEEE J. Ocean Engineering; Hastie et al. 2018 J. Applied Ecology].

Stanley's research has developed strategies for screening microalgae to evaluate their biotechnological potential [Slocombe et al. 2015 Scientific Reports].

Objective 2: *Undertake interdisciplinary aquaculture health and welfare research*.

Improved understanding of macro-algal evolution [Brawley et al. 2017 PNAS, De Clerck et al. 2018 Current Biology] has underpinned our leadership of the £5M GCRF GlobalSeaweedSTAR programme [Cottier-Cook, Gachon] that is growing a sustainable artisanal seaweed industry in developing countries and setting global policy in the field [Cottier-Cook et al. 2016 United Nations University Policy Brief].

Davidson's research has contributed to the assessment of the global impact of harmful algal blooms (HABs) [Berdalet et al. 2016 J. Marine Biological Association UK], and has developed an online HAB risk assessment system for the aquaculture industry. This research also safeguards human health through its support of our delivery of Biotoxin Producing Phytoplankton Monitoring for Food Standards Scotland and contribution to EU policy though the working group that is harmonising monitoring practices in Europe **[Case Study 2]**.

We lead [Davidson] a BBSRC/NERC £1.1M consortia (stakeholders: MOWI, Marine Scotland, Crown Estate Scotland, Willis-Towers-Watson) evaluating the potential for offshore finfish aquaculture to increase capacity while reducing the impacts of sea lice and contaminants.

Future aims and goals

In line with UHI's Research and Impact Strategy (**IES** page 4) we will continue to lead internationally important research and innovation in environmental science, and to apply our findings to the most pressing scientific, societal, and enterprise questions and needs.

We will use state of the art robotic underwater and airborne vehicles, in conjunction with conventional ship and terrestrial field campaigns, molecular biology, analytical instrumentation, satellite technology, novel biogeochemical sensors, laboratory process studies, mathematical models and socio-economic approaches to provide a quantitative understanding of environmental change, now and in the future in marine and terrestrial systems including open oceans, coastal seas, peatlands and freshwaters.

To meet international, national and regional priorities (e.g., the global climate emergency, post COVID-19 economic recovery, the BEIS industrial strategy, Scottish Funding Council KE requirements of the University Innovation Fund and Highlands and Islands Enterprise priorities and regional business need) we have set goals within our three themes to meet key environmental challenges of the next decade and beyond.

UREC

What are the physical, ecological, and biogeochemical drivers and responses to climate change? Can we improve our understanding and predictions of these?

Develop detailed predictive knowledge of global, regional, and local changes in natural environments. We will develop a deeper understanding of mid and high latitude heat, carbon and freshwater fluxes and oceanographic circulation at a basin scale (e.g., the UK-OSNAP project); undertake high resolution observational process studies and modelling; producing detailed characterisation of key processes affecting the fate of organic matter from source-to-sea (e.g., the UKRI FREEDOM and LOCATE projects).

Evaluate the biogeochemical and ecological significance of environmental change. We will further our holistic understanding of marine ecosystems and biogeochemical cycling through better representations of the underlying processes acting across different scales. We will unravel the role of peatland microbial communities in the global peatland cycle and their responses to droughts and wildfires, facilitating improved land management (e.g., Andersen's 5-year Leverhulme Leadership Award programme of research on peatland resilience).

Investigate the implications of the declining Arctic cryosphere. We will study the impacts of sea ice retreat on the ecology and biogeochemical cycling within the Arctic, and the oceanic controls and impacts of accelerating loss of glacial ice (e.g., the UKRI Kang-Glac project).

PatE

How can use of the natural environment be sustainably managed for the benefit of human-kind, and nature?

Understand how environmental contaminants affects ecological health. We will quantify exposure to, and impacts of, environmental contaminants in the natural environment whilst also identifying practical solutions to reduce risks. Our focus will encompass legacy and emerging contaminants of concern, including plastics, considering impacts from the organism to the ecosystem level.

Develop new methods for sustainable management of the environment that include local people, communities, and users. We will work with stakeholders to support sustainable management of the marine and terrestrial environment. We will improve spatial planning methods, and conduct research to support sustainable aquaculture, tourism, and energy extraction; seeking to reduce local poverty and conflict between industry and society (e.g., the GCRF OneOceanHUB project). We will develop new frameworks to improve decision making and management solutions for peatlands, forestry, and uplands to maximise cost-effectiveness and deliver benefits for nature and society.

We will support initiatives and projects that create a step-change in sustainability. We will assess the socio-economic and cultural benefits of human use of the environment bringing citizens, businesses, researchers and the third sector together to create lasting solutions of benefit to communities and ecosystems alike. We will seek to embed a 'circular economy' approach, developing approaches that maximise the sustainable utilisation of finite resources (e.g., the Phos4YOU and HUGE projects).

EaNR

What approaches will build and maintain sustainable blue and green economies so that we can continue to deliver benefit from natural capital without degrading its health and productivity?

Further develop and apply solutions to evaluate and mitigate the environmental impact of, and optimise best practice in, global aquaculture and fisheries. Development of our existing sea lice and benthic impact modelling software will provide advanced tools for the aquaculture industry and regulators. We will develop methodologies to minimise nutrient waste products (Robinson's RCUK Future Leaders Fellowship). We will further develop resilience in both finfish and shellfish aquaculture, through improved risk assessment and rapid alert tools for the global industry that mitigate threats to aquaculture such as HABs and sea lice (e.g., the UKRI Off-Aqua and Malaysian-HABs projects) through the integration of remote sensing, monitoring and modelling. We will develop novel approaches to underpin sustainable seaweed farming (e.g., the GCRF GlobalSeaweedStar project). We will facilitate sustainable fisheries management through research into emerging fishing techniques and selective fishing gears.

Evaluate the impact of marine structures on natural populations. We will evaluate the impacts of installing, operating, and removing marine structures on regional and ecosystem-scale processes including benthic secondary production and the spatial distribution of mobile predators and prey. We will determine physical impacts on seabirds, noise impacts on marine mammals and hydrodynamic impacts on predator-prey interactions (e.g., the EPSRC, NERC & NNSF China co-funded INNO-MPP project). We will quantify the biophysical interactions between offshore energy infrastructure and other marine industries providing tools for regulators and industry.

Improve understanding of the interactions between climate and land management. We will develop and validate new techniques to monitor peatlands, combining satellite technology, drones, and ground surveys to improve operational land management in climate extremes (e.g., the NERC FIRE BLANKET project). Through our involvement with multi-disciplinary research programmes on Scottish barley landraces we will contribute phenotype data from field trials to help identify the genes responsible for the unique tolerance of these landraces to trace-element deficient soils and challenging climatic conditions, allowing plant breeders to produce more resilient modern varieties.

Develop and apply biotechnological approaches to optimise the use of marine biomass. We will further develop seaweed as a renewable carbon resource within integrated bio-refineries to support sustainable production of food, chemicals, and fuels (e.g., the EU IMPAQT project). We will work with industry to improve the conversion of fisheries waste through microbiological biotechnological approaches, to replace petroleum-based polymers.

Open Research Environment, Research Integrity and Data

We encourage open access publication and support this with a specific publication fund.

UHI's Research Ethics Framework promotes research integrity. We seek to achieve a fair balance between a researcher's right to academic enquiry whilst adhering to appropriate ethical standards (**IES**, section 2). Training and assessment ensure that research staff and students understand and meet these standards.

We are fully compliant with the Concordat on Open Research Data (**IES** section 2). We submit data to appropriate repositories, for example the British Oceanographic Data Centre, the UK Data Archive Centre for Marine Biodiversity, NCBI's Sequencing Read Archive, the European Nucleotide Archive, NCBI GenBank database and the CEFAS Registry of Aquatic Pathology. We have registered appropriate datasets with EMODnet (European Marine Observation Data Network) and will use Google Datasets Search for future datasets. SAMS is a partner of MEDIN, a UK wide initiative to develop standards in the marine data environment and make datasets more discoverable. We also look to apply FAIR (Findable, Accessible, Interoperable, and Reusable) data principles. We run servers (ERDDAP, THREDDS and GeoSERVER) which expose our datasets more widely to the international community in formats such as netCDF, WMS and WFS.

2. People

Staffing Strategy and Staff Development

We employ scientists with expertise across environmental science. Appointments are driven by the research and impact objectives within our three interdisciplinary themes (UREC, PatE, and EaNR).

In total MESE encompasses 70 scientists (48 identify as male and 22 as female). Since REF 2014, we have had the following staff changes in our REF UoA7 category A staff cohort. Category A staff have increased by 10 heads from 38 to 48 (33.45 to 42.22 FTE) as described in Table 1.

	Arrivals		Promotions		Departures	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Director			1	1		2
Professor	1		4	3	4	
Reader				1		
Senior Lecturer	1				2	
Lecturer	5	3	5	2	1	1
Senior Research Fellow	2					
Research Fellow	3	3				
Other	1	1			5	
Retired					2	1

Table 1: Category A staff changes 2014-2020.

We have strengthened our international base by appointing PIs from Bulgaria, the Netherlands, Russia and Serbia and research staff from Chile, France, Germany, Italy, the Netherlands, Poland, and USA. Visiting Professors, Fellows and Researchers have come from Australia, China, Hong Kong, India, the Netherlands, Nigeria, Norway, Spain, Sweden, and USA.

Our activities are fully in line with the Concordat for Researcher Development (**IES** section 3). Our recruitment and selection procedures are transparent and open to all qualified applicants regardless of characteristics. All our roles have clear person and job specifications which identify the relevant skills required for the post. A focus of our recruitment has been to appoint junior staff who we support and develop along a career trajectory into future leaders. Fourteen (35%) of our category A staff who now hold PI positions ranging from lecturer to Professor began their careers with UHI as early career researchers. Our most recent internal appointment to PI has progressed through two post-doctoral appointments before this promotion.

Training opportunities are available across UHI to support professional development for all categories of staff regardless of contract type. As well as specific *on the job* training, we support a Learning and Development (L&D) programme that includes science leadership and project management through to networking and staff supervision. Staff are encouraged to attend regular L&D sessions on various topics, take weekly opportunities for writing (grants/papers), obtain guidance and training on fellowships/grants, as well as how to write a high impact paper. Our researchers also have access to wider science networks which offer funding and training to support career development and professional networking (e.g., via the Marine Alliance for Science and Technology for Scotland (MASTS) and the Scottish Alliance for Geoscience, Environment and Society, SAGES, UK Challenger Society).

Researcher development and career progression at all levels is supported by the University (**IES** section 3), MESE and Academic Partners through:

- Mentoring scheme with UoA7 staff acting as mentors and mentees, operated through UHI's Learning and Teaching Academy
- A conference attendance fund
- A sabbatical scheme allowing staff up to six months to focus on an area of strategic research
- Academic partners, MESE, and KE Groups offer small grants for pump-priming, facilitating networking, or for small items of equipment
- A biennial Research Conference
- An annual Post Graduate Conference
- Support for cross partner mini sabbaticals to enhance working relationships
- Grant proposal development workshops and paper writing retreats for ECRs
- Challenge Funds to encourage cross-partner KE activities
- Coordinated streaming of research seminars across MESE

All research staff regardless of contract type participate in performance reviews to support personal development and career needs. This process is driven by the individual with clear responsibility on each researcher to identify their own development needs, seeking advice and support from their line management and mentor(s) as appropriate.

Open-ended contracts are offered to all researchers in place for four years, and all but one of our category A staff are on open-ended contracts. We do not distinguish between staff on different forms of contract enabling them to set career objectives and take ownership of their own futures. Career progression and promotion are based on a combination of research, education, enterprise, and management activity. 13% of our research staff work part time at all levels including Professor.

Support and Promotion of Equality and Diversity

UHI has a unified equality and diversity policy which underpins our investment in people and inclusive culture. Further unified people policies are being developed to ensure that all staff have the same central support for career success whilst enabling local decision making by academic partners. Athena Swan Bronze accreditation (**IES** section 3) demonstrates UHI's commitment to advancing the careers of women within the organisation with a specific action plan to support women's representation, career journey and progression of female students into academia. SAMS, where 55% of our researchers work, is applying for bronze accreditation as a department in its own right.

As part of our equality and diversity policy we are committed to identifying and minimising barriers to career development and progression. Since 2014 our category A staff gender split has improved from 74%:26% to 66%:33% male:female, and we have markedly increased the number of female staff in higher grades with 50% of the eight reader/professor appointments being female. One key factor in this progress has been UHI funding of up to ten places every academic year on the Advance HE Aurora Leadership Development Programme, supporting women to reach their leadership potential.

Many of our senior science management roles are staffed by women: Stanley is Associate Director of Science, Enterprise and Innovation at SAMS; Cottier-Cook is Head of the United nations University Associate Institute; Mouat and Angus are joint Heads of Marine Science and Technology at NAFC; Smith is Director of Research and Innovation at IC; Andersen ERI research theme lead. Narayanaswamy leads SAMS' Graduate School. Hatton was Associate Director for Research at SAMS and Heymans Head of SAMS' Science Department.

Support Mechanisms for Early Career Researchers (ECRs)

In addition to the general career progression support available to all staff that is outlined above ECRs (at both PI and PDRA level) are further supported through:

- Reduced teaching and administrative loads
- Mini three-month sabbaticals with £5K funding
- Support to apply for a range of levels of Fellowship of the Higher Education Academy
- Writing retreats and academic writing support
- Access to a Scholarship Fund for educational research projects
- Training and development opportunities through MASTS and SAGES
- Free attendance at UHI biennial research conference

To enhance their development PDRAs contribute, alongside or guided by more experienced staff, to the preparation of research proposals, undergraduate teaching, and are encouraged to co-supervise PhD and Master students.

PGR students

UHI takes part in the biennial national Postgraduate Research Experience Survey (PRES).
In 2019 we were rated first in the UK for student satisfaction in STEM subjects.

UHI was granted Research Degree Awarding Powers (rDAP) in 2017 and operates its own PGR quality assurance process. PGR students are supported at University level by UHI's Graduate School (**IES** section 3) and locally within partners (for example due to the number of students at SAMS it operates a local Graduate School that complements the University level support).

PGRs are funded from a range of sources. We led the €3.8M ALFF Marie Curie Training Network (2014-2018). We are partners in RCUK Doctoral Training Partnership (DTP) and Centre for Doctoral Training (CDT) initiatives. These are the E3 DTP (2014-2019), the E4 DTP (2019-2024), the SUPER DTP (2019-2024) and the NexUSS CDT (2016-20). Students have also been funded by the MASTS Graduate School (2009-present), the European Social Fund (2016-2022), the Bryden Centre (2018-2022), the SFC HydroNation PhD programme and a range of non-Research Council funders. In the first two rounds of SUPER DTP recruitment (2019 and 2020 entry), the selection committee competitively awarded UHI the largest number of studentships of any partner.

The number of doctoral degrees awarded in each academic year is presented in Table 2. Since the granting of rDAP (2017) we have increased our intake, and currently have 82 (75 PhD and 7 research Masters) students within the UoA.

Year	13/14	14/15	15/16	16/17	17/18	18/19	19/20	total
Completions	8	7	11	6	5	9	8	54

Table 2: Doctoral degrees awarded.

PhD topics are selected based on science excellence, guided by our overall research strategy. Students are appointed through an open competitive process. 46% of completions and 51% of current students are female. No information on protected characteristics is available to interviewers. Panel chairs undergo training in equality and diversity including unconscious bias. Since 2014, we have had PGRs join from nine countries.

PGR training is informed by the UKRI Statement of Expectations for Postgraduate Training and the Concordat for Researcher Development. The Graduate School organises generic training e.g. presentation skills, writing, viva training with subject specific training being provided by partners and

relevant DTP/CDTs. Students can participate in undergraduate teaching. Prior to embarking on this, they undertake a “teaching to teach” course.

PGRs are allocated a Director of Studies (DoS) and a supervisory team (typically 1-2 staff that provide interdisciplinary breadth). Students undergo a Training Needs Analysis that continues throughout their studies though six-monthly progress monitoring. Students are allocated an independent “Thesis Panel” (composed of staff who have subject knowledge but no direct project involvement) and also a “Third Party" monitor based at a different UHI partner with whom they can discuss any issues independently. PGRs can access support in areas such as careers, disability, and visas. A Hardship Fund is available, and students have also been able to draw on extra funding from the Scottish Funding Council and Research Councils to support their studies though covid-19 disruption.

Students are provided with a computer and desk space and drawn on IT infrastructure and library resources. Electronic resources include a dedicated PGR area on UHI’s virtual learning environment that provides all documents and guidance that a student may need during their studies. They can access laboratory and field equipment and technical support (see section 3). From 2014-20 our PGR students have undertaken research in many locations in the UK and internationally including the Arctic, Chile, the North Atlantic, Norway, the Pacific and Siberia.

Student research is funded by their Training Support Grant. They also have access to UHI financial support for conferences and external training and are supported to apply for additional funding e.g. Dees won a MASTS small grant to purchase marine drifters, Cocking obtained RCUK funding for a hyperspectral camera, Martin obtained a Carnegie Scholarship. Students give seminars, organise journal clubs, attend conferences, write articles, and contribute to scientific discussion.

Our **PGR research has been recognised nationally and internationally,** for example Kati Michalek was the LANTRA Learner of the Year for Higher Education in 2017. Winnie Courtene-Jones was the 2017 P1 Marine Foundation National Student of the year for PhD Research and the first Chair of the EuroMarine OYSTER Network (Orienting Young Scientists of EuroMarine). Students are actively encouraged to publish their work in high impact journals, for example: Courtene-Jones et al. Environmental Pollution (2017); Dees et al. *PNAS* (2017); Strittmatter et al. *Plant Cell and Environment (2016)*.

Careers guidance information is provided through a range of seminars including interview technique and CV preparation and though on-line resources.

UHI and its students’ association (HISA) encourage engagement with students in decision-making. Two PGR student representatives sit on UHI’s Research Degrees Committee and one on the Research Committee that looks at wider University research strategy. Individual partners have student representation, for example a student representative sits on the SAMS Board of Governors.

We have provided **three Deans of the MASTS and SAGES Graduate Schools** (Miller, Calder, Howe) thus defining the environmental science PGR training agenda across Scotland. Davidson was a member of the NERC Training Advisory Board that set the strategy for environmental science PGR training UK wide. We also **provide doctoral level training** for students from other universities via NERC advanced training courses the Industrial Biotechnology Innovation Centre, the Industrial Doctoral Centre for Offshore Renewable Energy, the Bryden Centre, the SUPER DTP and the NEXUSS CDT.

3. Income, infrastructure and facilities

Our research and impact objectives are underpinned by competitive funding capture and state of the art facilities and research support structures.

Income

Since 2014, we have won £106M of research, KE and enterprise income including £25M from research councils (Table 3). As outlined above, this has included the leadership of major UKRI consortia, leadership of a major UKRI Global Challenges Research Fund grant, a RCUK Future Leaders Fellowship, a Leverhulme Leadership Award and UKRI National Capability funding. As also detailed above we lead and collaborate extensively on EU research programmes.

Year	13/14	14/15	15/16	16/17	17/18	18/19	19/20	Total £ million
RCUK	4.498	4.648	2.892	3.236	3.669	3.306	3.412	25.661
Research & KE Total (inc. RCUK)	9.376	9.696	7.920	8.738	9.245	9.379	9.220	63.574
RCUK research income in kind	0.126	0.001	0.001	0.027	0.306	0.584	0.154	1.200
Enterprise	2.049	1.838	1.673	1.860	2.201	1.967	1.771	13.358
Total	11.551	11.535	9.594	10.625	11.752	11.930	11.144	78.132

Table 3: Income by year (£ million).

We seek to obtain research income from UKRI, EU, and other funders to build and exchange knowledge and generate impact related to our research themes and in line with UHI's RKEC strategy and the impacts of BREXIT and Covid-19 (**IES** sections 2 and 4). Sub-FEC research is subsidised by financial surplus from targeted commercial work that also supports our impact activities.

Senior managers have undertaken unconscious bias training to ensure that we do not discriminate when allocating funding or research support. We operate a support, screening and reviewing systems to maximise the quality of grant and commercial proposal submissions. Our income split is 69:31 male to female, closely mirroring the category A staff gender ratio of 66:33.

Partner contract offices and enterprise arms support research grant, KE and enterprise bid development and consultancy. UHI has a central officer to support consortium building and bid writing. Financial support is available to engage in "Grand Challenge" application development.

Infrastructure

The location of our partner campuses within the Highlands and Islands and our direct access to the field, provides **a magnificent natural "facility" for research** that is highly attractive to collaborators. We have direct access to both sheltered and high-energy environments that are ideal for aquaculture and renewable energy research, respectively. We are also adjacent to contrasting areas of shelf-sea and can easily access deep-water environments. The Flow Country is the largest blanket bog in Europe and hence of particular importance for climate change research.

SAMS has been an international centre for fundamental and applied marine research since 1884. It operates from a modern facility near Oban on Scotland's west coast. The seafront laboratory boasts

direct access to both deep fjordic coastal water and intertidal zones and direct access to the NE Atlantic.

ERI operates from Thurso on Scotland's north coast overlooking the dynamic waters of the Pentland Firth, a contrasting environment to the west coast. ERI enjoys easy access to the flow country peatlands an outstanding natural laboratory of global significance for blanket peatland habitat with upland, lowland, and coastal settings. Key research sites include RSPB Forsinard Flows and Plantlife Munsary Peatlands.

NAFC is located in Scalloway on the Shetland Islands, a centre for fishing, aquaculture and marine related industries. NAFC is based on the coast with unique proximity to, and very close working links with, maritime industries and the environments in which they operate.

RLI was established in 2012 in response to a need in the freshwater management sector for greater research and training to support sustainable resource management and conservation. Based within the An Lòchran campus of IC it is close to a range of freshwater environments. A mobile field laboratory maximizes access to these sites.

AI based in the Orkney Islands opened in 2002 and undertakes research into the development and commercialisation of new crops and plant products.

National Facilities

We host at SAMS two UK National Facilities the Culture Collection of Algae and Protozoa (CCAP), **and the Scottish Marine Robotics Facility (ScotMRF) that are** supported by UKRI-NERC.

CCAP maintains ~3000 strains of microbes and seaweeds (www.ccap.ac.uk) providing a unique biodiversity resource for academics and industry. Strains are supplied worldwide. The online catalogue provides culturing and provenance information, photographs, barcode sequences and bibliography.

ScotMRF provides an exceptional range of capabilities that support academic, regulatory, and commercial activity related to the autonomous study of the marine environment. Researchers eligible for a NERC research grant can obtain access to ScotMRF to support their research. Its technologies span the atmosphere, ocean, and ice, including Gliders (2); Autonomous Underwater Vehicles (4); Autonomous surface vehicle (1); Remotely Operated Vehicles (2); Remotely Piloted Aircrafts; Drifters. Capabilities range from benthic mapping to evaluation of surface fluxes. ScotMRF provides training, being integral to the NERC CLASS project and the NexUSS CDT.

Research Vessels

We operate a fleet of **five MCA coded coastal research vessels** and other smaller vessels (Table 4, below).

RV Calanus (decommissioned 2020)	SAMS	20m category 2
Seòl Mara	SAMS	10m category 3
MFV Atlantia II	NAFC	12m category 2
MV Moder Dŷ	NAFC	13m category 2
RV Aurora	ERI	7m category 3

Table 4: Research vessels.

Aquaria

Our NAFC based 620 m^2 **Marine Hatchery** hosts algae production resources including temperature-controlled rooms and associated laboratory facilities. Systems include filtration, UV disinfection and temperature control. The 160 m^2 **Alan Ansell Aquarium** at SAMS consists of both indoor and outdoor facilities. The indoor facilities include an experimental area, a mezzanine floor and communications room, and numerous photoperiod and constant temperature rooms whilst outside holds raceways and tanks. Both have dedicated technical support and hold Home Office Establishment licences.

Experimental Seaweed Farms

We operate two **experimental seaweed farms,** including both the first and largest (30 hectares) experimental facility in the UK. Associated with these farms is a **seaweed hatchery**, dedicated to the out-planting and cultivation of strains for research and commercial supply.

Artificial Reef

The **Loch Linnhe Artificial Reef complex** consists of 30 individual reefs in water up to 30 m deep. This highly complex habitat allows scientific study of benthic species. It is now used for decommissioning related research [Wilding et al. 2014 Marine Environmental Research].

Sensor Arrays

OSNAP contributes to the North Atlantic observing system. The 5-year (€6.2M) EU Interreg project Compass, has established a network of oceanographic and acoustic moorings within and adjacent to **marine protected areas** providing a clearer understanding of how changes in oceanography impact underwater habitats and organisms. We have also maintained an **oceanographic mooring** near Tiree since 1981, **Arctic Observations** since 2002 (Kongsfjorden) and 2006 (Rijpfjorden), and the **Lorne Pelagic Observatory** (biogeochemistry) since the 1970s.

Facilities

We have a wide range of regularly serviced and calibrated equipment to ensure data quality and reproducibility, along with the expertise to deploy it. We participate in national and international calibration exercises and working groups. Equipment is upgraded using university capital and competitive research grant funding.

Marine (SAMS, NAFC, ERI):

Oceanography: CTD systems with rosette samplers, fluorometers and oxygen probes, Acoustic Doppler Current Profilers, current meters, mooring equipment.
Seabed sampling: Epi-benthic sled, dredges, corers, grabs.
Plankton sampling: High-speed plankton sampler, acoustic zooplankton and fish profiler.
Fishing gear: Trawls, seines dredges and traps.
Other: Underwater TV, digital cameras, automated water samplers, seabird-tagging equipment.

Freshwater (RLI, ERI, SAMS):

Mobile Aquatic Biodiversity Studies Field Laboratory: allowing on site sample processing and analysis use of specialist sampling/monitoring equipment.
Environmental Characterization equipment: Underwater Sonar and cameras, water quality testing.
Biotelemetry equipment: electronic ID tags and detectors.
Electrofishing equipment.
UK Freshwater phytoplankton collection: within CCAP.

Terrestrial (AI, ERI, RLI, SAMS):

Eddy-Covariance Flux Towers.
Greenhouse Gas sampling equipment including EGM-4 portable system.
Environmental monitoring: Automated water level loggers, soil temperature/moisture probes, PAR sensors.
Peat coring equipment: Soil auger, Russian peat corer, peat depth probes.
Snow ice monitoring: Sea Ice Mass Balance Array (SIMBA) system.

We host a wide range of **analytical** and **support facilities**:

Biogeochemistry facilities (SAMS, ERI):

Inductively Coupled Plasma Mass Spectrometry, Inductively Coupled Plasma Optical Emission Spectrometry, Oxygen isotope and Isotope Ratio mass spectrometers, Carbon/ Nitrogen, Total Carbon, Total Organic Carbon and Inorganic Nutrient analysers, High Performance Liquid and Gas Chromatography, Alpha, Beta, Gamma counters.

Geology laboratory (SAMS) includes multi-sensor core measurement of p-wave velocity, gamma density, magnetic susceptibility, electrical resistivity, and particle size analysis by laser-diffraction.

Microbiology laboratories (SAMS, ERI, NAFC) including containment 2 facilities containing laminar flow cabinets, filtration equipment, constant temperature rooms, autoclaves, incubators, and bioreactors. Molecular laboratories with PCR and qPCR thermal cyclers, nanodrop spectrophotometer, gel electrophoresis and Agilent 2100 Bioanalyser, electrophoresis room with dark room, digital gel capture system, fluorescent and colourmetric plate readers.

Genomics laboratory (IC) hosts a liquid handling robot, Standard thermocyclers (6), quantitative thermocycler for eDNA, 192 parallel sample DNA fragment analyser, zero agarose gel electrophoresis system, next generation DNA sequencer.

Optical and **microscopy** facilities (SAMS, ERI, NAFC) include the UK's first Imaging FlowCytoBot, Flow Cytometers and a FlowCAM. Confocal, electron, fluorescence, high power conventional (8) and inverted (10) microscopes.

FTIR laboratory (SAMS) we have recently established a Fourier-transform infrared spectroscopy laboratory through philanthropic funding to support micro-plastic research.

Histology laboratories (SAMS, NAFC).

Radioisotope laboratory (SAMS) Scottish Environment Protection Agency (SEPA) inspected, with performance being "Excellent".

ICT and Information Services (all partners). We enjoy state of the art video conferencing facilities with Cisco Webex and MS Teams being used routinely. Other cross partnership services include WAN, LAN, Wi-Fi, and telephony. Other ICT is managed at partner level including user directories, file services, desktop support and printing. Research specific ICT includes our high-performance computing cluster, bioinformatics systems, a photogrammetry suite, and big data servers. Specialised services to support research data management include programming, GIS, database design and management, data delivery websites and informatics. We have recently purchased a 60TB high performance storage system for Web data services.

The UHI **Library Service** offers services to support research across UoA7 with a wide range of electronic resources including links to the National Library of Scotland eResources and Open Access Image Collections. Our multi-search online tool provides one-stop searching across all eResources and print collections. Traditional libraries exist in each partner and specialist resources are available

at some, such as SAMS' membership of the UKRI/NERC Library Consortium providing access to over 4,000 journals.

We have a large collection of preserved **biological samples** (SAMS, NAFC), including historic deep-sea benthic samples now being used to study micro-plastics.

Collaboration with the "Institute of Health Research and Innovation" Research Cluster provides access to further analytical equipment related to genetics, immunology, lipidomics, and proteomics.

Human Resources

Within MESE we have a **pool of technical support staff** (currently ~40 FTE). These individuals support research and impact, each having specific expertise. They also support PhD students through provision of training and support.

In addition to UHI's central communications team, across UoA7 partners we employ **~7 FTE communication and marketing staff**. SAMS is an influencer in marine science with more than 10,000 Twitter, 6000 LinkedIn, and 1000 Instagram followers.

Our staff are regular users of research infrastructures, particularly vessels and equipment of the NERC marine facilities pool, with 39 cruises undertaken since 2014. We provide marine glider expertise for the Marine Autonomous Robotics Systems (MARS) facility at the National Oceanographic Centre.

Safety, Health and Environment

All our research adheres to safe systems of work. SAMS' safety, health and environmental management systems are certified by Lloyd's Register as meeting the requirements of ISO 14001:2015 and 45001:2018.

4. Collaboration and contribution to the research base, economy and society

Our success in meeting MESE's objectives is attributable to national and international scientific leadership and partnerships with researchers, policy makers, businesses and the public as detailed below. Since REF2014 we have made a significant contribution to the environmental science research base via academic literature, with category A staff publishing 974 outputs that have received more than 15,000 citations.

International collaborations

Research facilities:

We are partners in **The European Marine Biological Resource Centre** (EMBRC), a marine focussed pan-European Research Infrastructure Consortium (ERIC) of 20 institutions / 9 countries. The H2020 ASSEMBLE+ is a sub-project of EMBRC, allowing transnational access to CCAP.

We are also partners in the **European Marine Biological Research Infrastructure Cluster** (EMBRIC). This ten-country 26 partner ERIC promotes activity in the fields of drug discovery, aquaculture, bioremediation, cosmetics, and bioenergy.

The **CCAP** and **ScotMRF** national facilities constitute a resource of national and international significance for marine science. In 2017/18, over half of cultures provided by CCAP were to overseas customers. ScotMRF supports projects in the UK and in international locations (e.g. Chile, Svalbard (Norway), and Tanzania).

These partnerships along with the other facilities detailed in section 3 and our unique "natural laboratory" attract national and international scientific collaborators. Since 2014 we have hosted ~ 300 visiting international scientists (for at least 4 days) from over 20 countries and our scientists have also participated in more than 700 collaborations abroad (Figure 3).

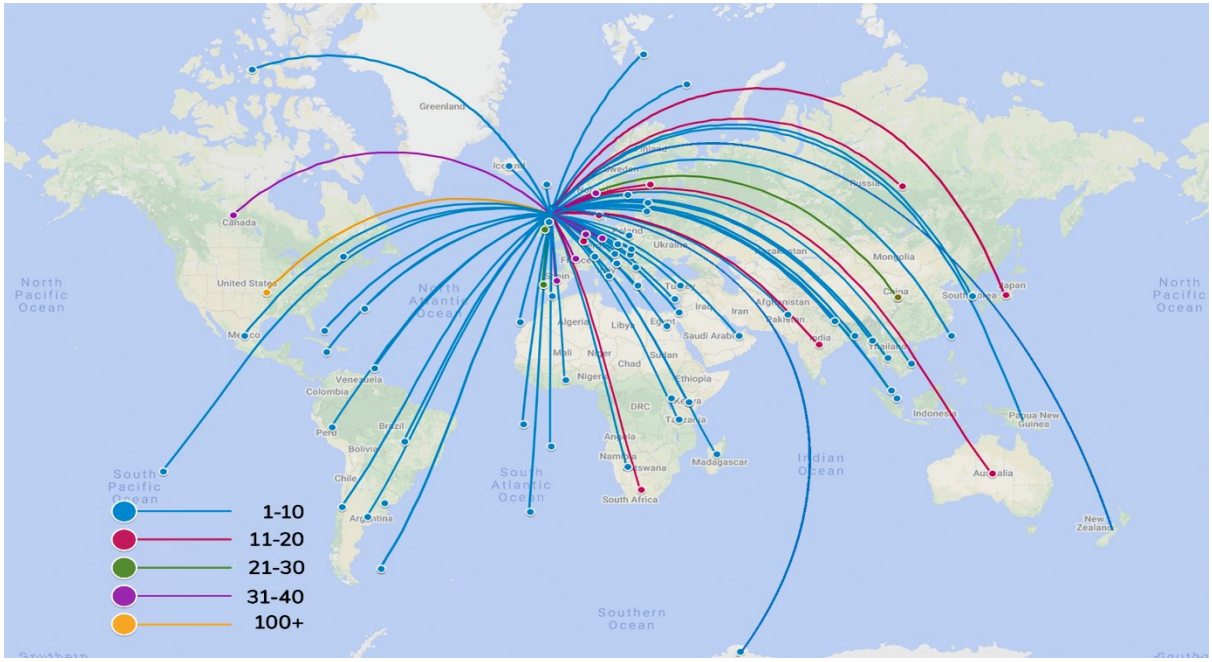

Figure 3: Location of international collaborations: colours depict the number of partnerships.

International Research Programmes:

We lead and participate in many programmes of international significance. Examples include:

- The **OSNAP consortium** (US, UK, Canada, China, France, Germany and the Netherlands) is studying overturning in the subpolar North Atlantic [Cunningham].
- We are active in Arctic regions with significant collaborations with **Norwegian and Canadian institutes** [Cottier et al.], with our SIMBA sensors being important to the €130M 19 country **MOSAiC Arctic research project**.
- We support sustainable aquaculture in developing countries, e.g., as part of an international consortium working to **prevent the extinction of vultures in S. Asia** [Taggart, **Case Study 3**].
- The £5M **GlobalSeaweedSTAR** programme supports sustainable development in both African and Asian DAC countries [Cottier-Cook, Gachon].
- The £20M 59 partner GCRF **OneOceanHub** project is building research capacity in Africa and the Pacific Islands [Narayanaswamy, Fox].
- The £0.5M **EPSRC/NERC/NNSFC renewables project INNO-MPP** includes three UK and three Chinese partners [Benjamins, Hughes].
- Collaboration with Sun Yat Sen University (China) studying **eutrophication in Hong Kong** [Davidson].
- Habitat mapping in **Patagonian Fjords** funded by the Chilean Research Council [Howe].

We also participate in many EU funded projects, examples include:

- The 62 partner, 18 country, **AtlantOS** project is integrating Atlantic Ocean observing systems [Cunningham, Inall].
- **CACHE (**€3.6M, 10 partners) investigating calcium in a changing environment [Last].
- **Genialg** (€12.2M, 19 partners) studying the genetic diversity of macro-algae [Gachon].
- The **iAtlantic** programme is assessing the health of deep-sea ecosystems across the Atlantic Ocean [Cunningham, Inall].
- **PRIMROSE** (€3M, 10 partners) that is developing harmful algal bloom early warning approaches [Davidson].

International Academic Leadership includes:

- **Andersen** led the Restoration Expert Group for the International Peatland Society.
- **Burrows** sits on the International Heatwaves and the EuroMarine Climate Change Refugia working groups.
- **Cottier** is the UK representative on the Marine Working Group of the International Arctic Science Committee.
- **Cottier-Cook** is a member of the Expert Network for the UK Commission for UNESCO.
- **Davidson** is a member of the GlobalHAB Scientific Steering Committee.
- **Gibb** is Vice President of European Association of Chemistry of the Environment and Chair of the Environment Committee the European Offshore Wind Deployment Centre.
- **Heymans** is seconded as the Executive Director of the European Marine Board.
- **Owens** (SAMS Director) is Chair of the Partnership for the Observation on the Global Ocean.
- **Taggart** sits on the Technical Advisory Committee for the “Saving Asia’s Vultures” forum.
- Staff are members of ICES working groups (**Cottier-Cook, Davidson, Mouat, Shucksmith, Wilding, Williamson**).

International Partnerships:

SAMS is the only marine research institute to be an **Associated Institution of the University of the United Nations (UNU)**. This partnership supports international collaboration to promote research, postgraduate training and knowledge exchange focusing especially on developing nations.

We have MOUs with international partners including: University Centre in Svalbard, Norway; The United Nations University International Network for Water, Environment and Health; Chungnum University, Korea Polar Research Institute, Korea; University of Konstanz, Germany; BioPol and the University of Akureyri, Iceland; Madinat Zayed Colleges, Higher Colleges of Technology UAE; UNC Wilmington, USA.

Our staff work internationally, with a number holding external positions:
- **Cottier** and (researcher) **Reinardy** are Adjunct Professors at the University of Tromso and University Centre in Svalbard (UNIS) respectively.
- **Gibb** is an Honorary Professor with Changsa University of Science and Technology and a visiting professor at the Hunan Institute of Engineering, Xiangtan (China).
- **Hughes** is an Honorary Research Fellow at the University of the Seychelles.
- **Anderson, Inall**, and **Narayanaswamy** make significant contributions to the research and teaching at UNIS (Svalbard).

National (UK) partnerships:

We are involved in many multi-partner research projects with other HEIs and research organisations. Examples of major UK collaborative projects include:

- Leadership of the **Arctic PRIZE** consortium (£1.5M) [Cottier, Davidson, Last, Narayanaswamy] with Edinburgh, NOC, Oxford, St Andrews, Strathclyde.
- Leadership of the BBSRC/NERC Sustainable Aquaculture consortium **OFFAqua** (£1.1M) [Davidson, Dale] with Exeter & Stirling.
- Participation in the NERC marine autonomy projects **AlterEco** (£0.5M, 7 partners) and **CAMPUS** (£3M, 7 partners) [Inall, Davidson]. With Cefas, Exeter, Met Office, Newcastle, NOC, PML, UEA.
- The Innovate UK/BBSRC **SeaGas** (£2.8M, 6 partners) energy generation project [Hughes] with Cefas, The Crown Estate, Newcastle, QUB.
- Partnership [Andersen] in the **Flows to the Future** Project that aims to restore areas of blanket bog in the Flow country, developing our knowledge of carbon storage. This has led to the establishment of a **Peatland Science Center of Excellence.**

Staff contribute to the leadership of the environmental science research agenda across the UK, significant examples include:

- **Andersen:** National Peatland Research and Monitoring Group (Chair), National Peatland Group.
- **Andersen, Anderson, Davidson, Narayanaswamy** UKRI review panels.
- **Burrows, Cottier-Cook, Davidson, Inall;** Marine Climate Change Impacts Partnership report card contributions.
- **Cottier:** UK Arctic and Antarctic Partnership, NERC Cruise Program Review Group.
- **Davidson:** NERC Training Advisory Board and Joint Capital Allocation Group, NERC Advisory Network.
- **Fox, Inall, Tett:** DEFRA advisory groups.
- **Gibb:** Heritage Lottery Fund 'Flow to the Future Programme (Chair) Environment Committee European Offshore Wind Deployment Centre (Chair). Advisory Panel to the Scientific Advisory Committee of Scottish Natural Heritage.
- **Hatton:** NERC Science Board (Chair).
- **Howe:** NERC Radiocarbon Steering Committee.
- **Inall:** (Chair) and **Cunningham** NERC Marine Facilities Advisory Board.

- **Stanley:** NERC/TSB Algal Bioenergy Special Interest Group (Director), Scientific Advisory board of IBioIC (Chair), BBSRC Industrial Biotechnology and Bioenergy Strategy Advisory Panel, ETP Bioenergy working group, EPSRC Energy Strategic Advisory Board.

National (Scotland) partnerships:

- **Andersen:** Flow Country Rivers Trust (Trustee), Flow Country World Heritage Site Working Group, Plantlife's Munsary Peatland's management group.
- **Gibb, Inall:** Scottish Government Advisory Group for the Arctic Policy Framework.
- **Inall:** Scottish Science Advisory Council, Scotland's highest level science advisory body.
- **Mouat:** Scottish Inshore Fisheries Conservation and Management Group, Clyde 2020 Research Advisory Group.
- **Smith:** Trustee of Skye and Wester Ross Fisheries Trust (Trustee), Rivers and Fisheries Trusts Scotland (Board Member).
- **Williamson:** Engineer Award at the 2017 Scottish Renewables Young Professionals Green Energy Awards.
- **Wilson:** Scottish Natural Heritage Expert Panel.
- **Verspoor:** Tay Rivers Board (Chair).

We are partners in **MASTS**, with N. Simco (UHI VP Research) chairing its governing council. We lead/led a number of its themes and fora (Dynamics and Properties of Marine Systems: Cunningham; Oil and Gas Environmental Research: Wilding; Aquaculture: Hughes; Deep Sea: Narayanaswamy; Marine Planning and Governance: Greenhill, Shucksmith; Numerical Hydrodynamic Modelling: Aleynik. We are active within **SAGES,** with Inall being Director and Howe Head of its Graduate School. Cottier co-leads the Ocean/Climate Theme.

We have direct **links with many HEI's**, e.g., Tett and Inall are Honorary Professors at Heriot-Watt and Edinburgh Universities, respectively. Tett is an Emeritus Professor at Edinburgh Napier University. Narayanaswamy is an Affiliate Researcher at the University of Glasgow. Williamson holds a Research Fellow post at the University of Aberdeen. Bond holds a position at the Natural History Museum. Meredith and Clark of the British Antarctic Survey are visiting professors of UHI.

Other metrics relating to category A staff activity are summarised in Table 5.

Activity	Number
Fellowships of professional bodies	18
Grant Committee review meetings	15
Grant reviews	194
Conference/workshop organiser	69
Keynote/invited talks	196
Conference session chair	57
Journal editor	3
Journal editorial team	12
Special issue guest editor	7
Papers reviewed	551
PhD examinations	77
Research field trips	233
External committees	81
Prizes	12

Table 5: Measures of esteem for Category A staff.

KE and engagement with policy and commercial research users

Our KE activity seeks to maximise the societal impact of our research. KE is guided by the need for evidence, scientific input, and research innovation to support regional development, evidence-based policy making (locally, nationally, internationally), and industrial growth. UHI funds four core KE support staff and two-sector specific KE staff who support UoA7 activities. Allocation of Universities Innovation Funding also support the KE sectoral groups.

Examples of the translation of our research were presented in section 1. In addition, since 2014, we have hosted **four NERC Knowledge Exchange Fellowships** targeting wave and Tidal Energy (WTE), Aquaculture (2), and Oil and Gas (O&G). Each addressed sectoral challenges by linking research to industry and regulatory needs. For example, the WTE Fellowship demonstrated the feasibility of mapping biofouling risk to renewable energy devices. The work of the O&G Fellow on marine robotics led to a further NERC funded project: Ocean Data Tool, a collaboration with Marine Scotland and BP. The tool has since been used by BP in oil spill evaluation. We are members of Scottish Policy and Research Exchange (SPRE).

We host the **European Centre for Marine Biotechnology,** an incubator facility with nine current tenant companies. Adjacent to this, the **European Marine Science Park** (EMSP) houses a further 12 marine companies. Both operate in collaboration with Highlands and Islands Enterprise (HIE), our regional development agency. These facilities provide businesses with access to our expertise, research facilities and collaborative opportunities enhancing both these businesses and our related research though both formal and informal collaborations, and the hosting of undergraduate and postgraduate students. Phase two of the EMSP is currently under development and will include a Marine Bioprocessing Centre under our academic leadership. Closely aligned to the EMSP and the Argyll & Bute Rural Growth Deal is our bid to develop (i) an International Seaweed and Shellfish Industry R&D Centre; and (ii) a regional aviation, UAV Robotics, and Compliance hub.

We engage with key policy stakeholders such as the **Scottish Environment Protection Agency** (SEPA**)** and **Marine Scotland Science** (MSS) through regular meetings and briefings and by embedding our research with these users. For example, PDRA Rouse was seconded (50%, 3 years) to MSS to exchange knowledge in the field of Offshore Energy and PDRA Van Geel was seconded to MSS to support their underwater noise monitoring to meet Marine Strategy Framework Directive reporting requirements. We **liaise directly with industry,** for example Support Scientist Megan

Roachford was based at the major aquaculture company MOWI (2016-2018) to exchange marine modelling expertise and **UKRI Future Leaders Fellow Robinson is based in Mauritius** to interact with aquaculture stakeholders.

UHI are partners in the **Scottish Funding Council's Innovation Centres** with UoA7 undertaking projects funded by the Scottish Aquaculture Innovation Centre, the Industrial Biotechnology Innovation Centre, the Oil and Gas Innovation Centre and the Data lab.

Policy and society

Contribution to society is central to our impactful applied science ethos with key reports to government and other stakeholders generated by the PatE theme being listed above. We have provided further policy advice in the following key areas:

We work closely with the Scottish and UK Governments. Inall sits on the **Scottish Science Advisory Council,** and Burrows has led major reports in the areas of **Blue Carbon** for Scottish Natural Heritage: e.g. [Burrows et al. 2014 Assessment of carbon budgets and potential blue carbon stores in Scotland's coastal and marine environment; Burrows et al. 2017 Assessment of blue carbon resources in Scotland's inshore MPA network].

We contribute to **UK high latitude policy**. Cottier was an invited panel member for the UK All Party Parliamentary Group for Polar Regions, and we provided oral [Inall] and written evidence to the Changing Arctic Enquiry of the UK Parliament's Environment and Audit Committee and have produced UK and EU policy briefing documents on the Arctic's impact on northern hemisphere weather and climate. Cottier supported FCO sessions in marine cooperation in the Arctic, and Inall and Gibb were involved in the development of the Scottish Government Arctic Policy Framework.

We work extensively in the field of aquaculture (global value ~ $250 Billion, Scotland ~£670M annually). We have provided **evidence in the Scottish Parliament** and to **Scottish Government.** Most notably Tett led the Scottish Government report into the "Environmental Impacts of Salmon Farming Aquaculture", and Burrows provided evidence to the Environment Climate Change and Land Reform Committee and the UK Parliament's Environmental Audit Committee. Hughes, Cottier-Cook and Davidson have sat on Scottish Government ministerial working groups. Cottier-Cook led a UN Think Tank on Water (INWEH) Policy Brief on the future of the ~$5 Billion global seaweed aquaculture industry and has advised the Environment Agency on the potential impacts of non-native species. Our work has advised seaweed harvesting policy decisions with Cottier-Cook leading a 2018 Scottish Parliament SPICe briefing.

With HIE, Ekosgen and Imani Development we conducted a **UK Government Regional Science and Innovation audit (SIA)** of the Highlands and Island region focussing on aquaculture, wave and tidal energy and marine biotechnology (MaxiMAR). This identified key strengths and growth opportunities and highlighted targeted opportunities for economic development.

Our research on **inshore fisheries** [Shelrmerdine] has supported the Shetland Shellfish Management Organisation in maintaining sustainable fisheries and attaining Marine Stewardship Council accreditation for brown crab and scallops (the only two such European fisheries to attain this). We have informed national policy, working with Marine Scotland and Inshore Fisheries Groups. Our marine spatial planning methods [Shucksmith] have attracted practitioner, NGO, political and academic interest across the globe.

Our **peatlands and carbon** research [Andersen] provides evidence of the climate benefits of peatland restoration that has been used in the IUCN Peatland Programme reports on forestry, peatlands and biodiversity and has been integrated in ClimateXChange policy briefs that provide independent advice to Scottish Government.

Our scientists undertake public and school presentations and visits, including activity supported by a Royal Society partnership grant to promote environmental science in primary schools. Our **visitor and outreach centre**, the Ocean Explorer Centre welcomes ~4,500 visitors annually. In 2019 we delivered 24 educational workshops to 539 school children.

Industry and economy

We have wide application of our research. Our enterprise arms work closely with industry to achieve an annual commercial turnover of ~ £1.9M though the application of our research (Table 2). Exemplar projects are:

Our **depositional modelling** software NewDEPOMOD evaluates the impact of fish farm activities on the seafloor. It is used by the industry regulator SEPA and under license by more than 90% of the UK's salmon industry. Its use extends to Chile, Canada, Norway, Australia, New Zealand, Spain, and Turkey [**Case Study 1**].

We have delivered **Food Standard Scotland's** regulatory shellfish safety programme for 16 years, applying our research expertise to protect shellfish consumers [**Case Study 2**]. This project also exemplifies commercial activity supporting research through its funding of high- power microscopes that are also available for research use and for generating a unique long-term data set.

We have developed software to model **sea lice connectivity** and dispersal and now deliver a commercial service for finfish aquaculture companies.

Based on NERC funded research we developed, manufacture and market **SIMBA** for the real time measurement of polar sea ice. Customers include Alfred Wegener Institute, Polar Research Institute of China, and University of Tasmania. We are refining the product for avalanche and flood monitoring in partnership with SEPA.

We have developed a photogrammetry process for the **assessment of marine growth on sub-sea structures**. Using this, we provide a service to oil and gas companies undertaking infrastructure decommissioning and offshore wind farm developers to provide essential environmental and design/engineering information.

Through our seaweed hatchery and seaweed farms we engage with the fast-developing **seaweed farming industry**, supplying 'seed' to farmers throughout Europe utilising knowledge gained from BBSRC, NERC, EU and private funding. We offer a consultancy service advising on all aspects of farming. Through CCAP we offer a service to farmers to manage site/region specific algal species stock for on-going reproduction and supply of seed.

We have a record of undertaking **independent scientific review of EIA** documents and providing support to governments, for example the Falkland Islands (oil developments), Papua New Guinea and Chile (deep sea mine tailings) and Scotland (impacts of aquaculture).

We undertake bespoke contracts to enable industry to make informed environmentally sound decisions. These include **mapping of seafloor** areas so that developers understand the complexities of sediment type and benthic communities, to developing monitoring programmes to detect change as **distilleries alter their production processes**. We have also studied **marine growth on flexible riser systems.** Customers include MOWI, William Grant and Shell, Chevron, New Crest Mining, Merck Pharma and EDF.

We undertake **commercial fisheries consultancy** for the public body Seafish and the Scottish and Welsh Governments and monitor non-native species for the Shetland Oil Terminal Environmental Advisory Group. Our **marine hatchery** provides facilities hire, including facilitating the upscaling,

and embedding, of lumpfish as a commercial management tool to control sea lice infestations on Atlantic salmon, and the isolation of novel antigen receptors from cartilaginous fish.

We provide **support and consultancy to the marine renewables industry** through the maintenance and operation of wave sensing equipment, the provision of acoustic seabed surveys and the analysis of spatial data within the policy context. We provide **anti-sea lice drug emamectin regulatory residue testing** for fish farm companies including MOWI; as well as water quality testing and/or environmental consultancy for wind farm companies (e.g., SSE and Npower) pre-, during- and post- construction of wind farms, including for the 443MW 103 turbine Viking Wind Farm on Shetland.

Our facilities and services are advertised on dedicated web sites (e.g., SAMS Research Services Limited www.SRSL.com) and are included in the Interface database.

Our enterprise staff engage with researchers to best utilise their science. To provide researchers and students with the innovation skills to commercialise their research we offer training workshops through UHI's "Enterprising Researcher" programme. The Create Unit of IC has produced a range of resources and training activities including entrepreneurship "train the trainer" events and the UHI business idea competition that offers advice and support and feeds into the national Converge Challenge competition.