Institution: Swansea University

Unit of Assessment: 7 Earth Systems and Environmental Sciences

1. Unit context and structure, research and impact strategy

1.1. Unit Context

Biosciences has expanded greatly since REF2014 where we were ranked 8th, with 40% of our outputs rated 4*. We now have over three times as many permanent academic staff across all career pathways, with ~78% submitted to REF2021 (100% Category A). The transformation has been assisted by >£8M investment in infrastructure to support new research, attract increased grant income, and support PhD students and postdoctoral researchers. Our submission focuses on achievements made by successfully implementing the objectives set out in the REF2014, how these achievements are enabled and supported by the unit structure and collegial research culture, and how this leads to our new five-year strategic plan.

Biosciences is one of six departments in the interdisciplinary College of Science (CoS) and supports subject-specific and interdisciplinary investigator-led, basic and applied research, guided by our over-arching strategic principles:

(1) Continue to invest in our collegial research culture focusing upon non-hierarchical interaction and exchange of ideas and support.
(2) Undertake environmental research with impact. We are committed to doing science with communities and for society, in line with the UN sustainable development goals and the Future Generations/Wellbeing Act 2015 of Wales.
(3) Maintain and grow strong interdisciplinary collaborations in blue-skies and applied research.
(4) Undertake internationally leading research and use Wales as a natural 'laboratory'.

1.2. Structure

In 2014, Biosciences submitted 12 staff (11.2 FTE) to REF (Unit of Assessment 7: Earth Systems & Environmental Sciences). Building on the excellent outcome, and the research strategy described in REF2014 (REF5), we have expanded to a complement of 39 faculty members: 29 Research (REF Cat A staff), 7 Teaching and 3 Innovation. Our diverse group also includes 10 independent fellows, 24 postdoctoral researchers, 14 research officers and 48 PhD students. Our research is supported by four preeminent facilities/interdisciplinary centres; the Centre for Biomathematics, the Centre for Sustainable Aquatic Research (CSAR), the biologging Visualisation Laboratory, and the research vessel and sea-going marine laboratory 'Mary Anning' (see also section 4).

Our research activity is co-ordinated through four research themes (Figure 1) which have evolved from the groups established prior to REF2014 (*The Centre for Sustainable Aquatic Research, the Dynamic Ecology Group, Swansea Laboratory for Animal Movement and Swansea Natural Products*). Theme members meet several times each semester to share research highlights and develop collaborative research ideas and strategy. Every two weeks theme leads meet with the Biosciences Research Committee to develop and advance our broader departmental research priorities. All research themes include researchers from

multiple laboratories, reflecting the collaborative nature of our research. Similarly, many researchers are affiliated with multiple themes (although each REF-submitted individual is listed under one theme for this exercise):

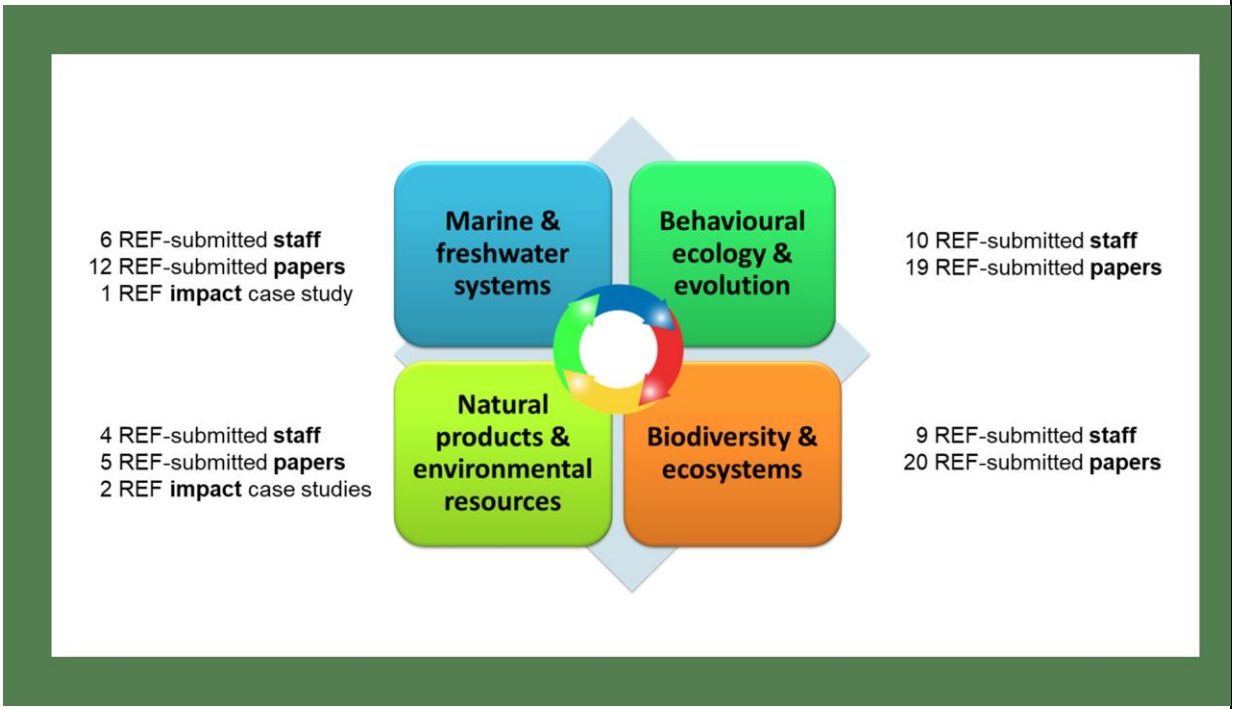

Figure 1. Biosciences Research Themes, associated staff members (REF Cat A staff only) and outputs.

Marine and Freshwater Systems builds on a strong history of aquatic research addressing fundamental and applied questions relating to sustaining ecosystem services. Key advances are, (i) identifying threats to the functioning of coastal and freshwater systems (Nature Comm. 2019, Nature 2020); (ii) demonstrating that Europe's rivers are congested with > 1 million barriers (part of a €6.2M project on river system management across 32 countries), (iii) proposing frameworks for habitat management based on a broader systems-approach, which include socio-economic factors (Nature Comm. 2019, Nature Ecol. Evol. 2019), and (iv) advancing theory and practice in coastal habitat restoration (Nature Comm. 2020).

Behavioural Ecology and Evolution interrogates the basis of behavioural and morphological adaptation from molecular to macroevolutionary scales. Research highlights include (i) the role of animal movement and energetics in the evolution of life-history strategies (Science 2014, Current Biol. 2018, PNAS 2020), a theme also supported through an ERC starter grant; (ii) the genetic and phenotypic control of reproductive strategies (e.g., PNAS 2014, Nature Comm. 2015); and (iii) the macroevolutionary consequences of traits including animal colouration and chemical defence (Nature Comm. 2014, PNAS 2015).

Biodiversity and Ecosystems concentrates on the mechanisms and functions driving biodiversity patterns and ecosystem dynamics, to better inform management and policy from local to global scales. Major advances include (i) quantifying community composition at global scales associated with land-use, land protection and habitat fragmentation (Nature 2015, Nature Comm. 2016, Science 2019), as part of an assessment of conservation measure

effectiveness, and our progress towards biodiversity targets (Science 2014, Global Change Biol. 2017); (ii) demonstrating the role of biodiversity in increasing ecosystem stability and multifunctionality (Nature 2015, Nature Comm. 2015, 2016, 2019); and (iii) assessing the latter over evolutionary timescales (Nature Ecol. Evol. 2017, Ecol. Lett. 2018).

Natural Products and Environmental Resources aims to maximise the benefits of natural resources while minimising environmental disturbance through applied research. The main research thrusts are (i) algal biotechnology, including the €5.5M ALG-AD project to develop new technology to derive valuable products from food and farm waste; (ii) biocontrol and fungal biology (2 patents filed in the REF period); and (iii) invertebrate biology. Collaborations with businesses and policymakers are central to the research.

1.3. Research objectives

1.3.1. Review of REF2014 objectives

We have successfully delivered on the major strategic research goals set out in the 2014 assessment:

i. **To grow our staff, research income and student numbers.**

We **recruited 23 internationally renowned scientists** and ECRs to enhance our strengths in marine biology, ecology, biotechnology and aquaculture, as well as build new strategic research areas including molecular ecology and evolution. We **reformulated our research themes** to represent our core strengths in line with our new appointments. The themes now play a vital role in researcher development and provide a clear route for researchers at all levels to feed into our research strategy. This complements weekly initiatives, such as our seminar series (including departmental seminars, a bespoke Biomathematics series and postgraduate seminars), Bio-lunches (bringing postgraduates and staff together) and our SciArt club, all of which contribute to our vibrant research culture.

We have achieved **sustained growth in research awards**, with an average +122% increase in annual grant funding. This corresponds to ~£600k per permanent academic member, almost double the £301k reported in REF2014. We have also increased the number of funding bodies from which we have attracted funding (e.g., European H2020 funding with >19M€ from INTERREG, ERDF, WEFO, EMFF; >4M€ from MSCA Innovative Training Networks; 2M€ ERC Starting Grant, >£1.5M to CSAR for sustainable cleaner fish programmes for the salmon farming industry).

ii. **To deliver a truly integrated, interdisciplinary research environment**

SU College of Science (CoS) provides opportunities to collaborate within and between disciplines, for example, the founding of our Biomathematics centre which catalysed interdisciplinary doctoral research and was supported by 3 cross-disciplinary appointments. We have also delivered **a £8.1M investment in preeminent core biological research infrastructure and research facilities** (section 3.2), enabling our strong interdisciplinary collaborations (see 1.4).

We have **increased the scale of our applied research**, with a focus on close individual engagement with industry collaboration (e.g. >£1.5M salmon farming industry to CSAR, €5.5M ALG-AD industry-based circular economy project creating wealth from waste), and wider strategic initiatives including SEACAMS ("Sustainable Expansion of the Applied

Coastal and Marine Sectors") and £4.6M SEACAMS2, both funded by the European Regional Development Fund (ERDF) and Knowledge Economy Skills Scholarship 2 scheme funded by the European Social Fund (ESF).

1.3.2. Future objectives

Capitalising on our successful growth during the past two REF cycles, our **strategic aims for the next REF cycle are to continue to lead the national environmental science agenda and fortify our international reputation for excellence in environmental research**, by:

(1) Strengthening our international partnerships that align with UN Sustainability goals and key international environmental programmes.
(2) Building on our leading role in Welsh environmental research, particularly that aligned with the Future Generations/Wellbeing Act 2015, the Welsh marine coastal economy and sustainable use of coastal resources, biophilic living and the green recovery from Covid-19.
(3) Establishing a new core facility for research into natural products, bioremediation and the circular economy, and strengthen industrial collaboration and commercialisation routes. This will be achieved through a major focus on a Swansea Natural Products bid.
(4) Expanding our environmental science remit beyond the current UoA to develop further collaboration with geography and engineering colleagues and capitalise on the establishment of the new SU Morgan Institute for Advanced Studies.
(5) Gain meaningful and substantial institutional overhead return to PIs to enable researcher-led development of strategic research goals and developing departmental priorities.
(6) Further support of our ECRs. This is particularly pertinent given the disproportionate impact of Covid-19 on staff at this career stage. Dedicated support will include targeting additional doctoral training funds, prioritising ECRs for internal PhD awards and establishing peer-to-peer coaching.

1.4. Research impact

Biosciences has adopted "Ecological Research with Impact" as the departmental ethos to address real world issues; and to create societal impact at regional, national and international levels through a) industrial collaboration, b) community engagement c) innovation and d) outreach. We have a history of engaging with external stakeholders, **collaborating with 100 industrial partners** (including commercial, governmental and charitable organisations) in funded research projects within the REF period. Notably, all our Impact Case studies arose from active research collaboration with industrial partners.

Swansea Biosciences is important regionally to Welsh science, informing best practice in ecosystem management (Welsh Government, National Resources Wales (NRW), and local conservation bodies). We also undertake activities with schools and colleges, fairs, the public, local radio and Welsh-medium TV. We contribute to successful, ongoing outreach activities including ORIEL Science, Soapbox Science and the Annual Swansea Science Festival, and we co-fund the Science Pavilion at the annual National Urdd Eisteddfod. UK-wide, our researchers interact regularly with learned institutions for outreach and community activities (panel members, journal editors etc.), with government policy bodies (e.g., Science and

Technology Committee on Japanese knotweed, Foreign & Commonwealth Office Science Advisory Group) and national media.

Internationally, our world-leading research has industrial and policy impact, e.g., informing the redrafting of the European Common Fisheries Policy, generating new biocontrol products to sustainably control arthropod pests across the world, informing the development of marine renewable energy installations, and new EU-level procedures for river barrier adaptive management. Our work features regularly in the international press (BBC World News, India Today, NY Times, MSN Latin America, Russia Today), with **media outputs in 65 countries** since 2017.

We have produced >750 publications in international peer-reviewed journals, which includes 32 papers in Nature, Science (excluding Scientific Reports) and PNAS. Our publications have been **cited >15,600 times**, with **23% in the top 10% of most cited publications worldwide**.

1.5. Interdisciplinary research

Interdisciplinary research is central to our research ethos and activity, with existing and new collaborations being supported through specific institutional funding calls. We also advance our interdisciplinary agenda with industry partners and government agencies (section 4). Focal points of interdisciplinary activity and capacity include:

The **Centre for Biomathematics** established in 2016 to foster interdisciplinary collaboration with Mathematics, Medicine, Computer Science, and Engineering is co-directed by academics from Biosciences and Mathematics. This has facilitated seven inter-disciplinary, University-funded PhDs (3 completed) and two quantitative/computational ecologists were appointed in Biosciences and one lecturer in Biomathematics. Staff and students benefit from the new Computational Foundry, a £32.5M world-class facility for research collaborations. The centre holds monthly seminars with national and international speakers and has organised national workshops for students and ECRs and will host the prestigious International Statistical Ecology Conference (ISEC) in 2024 (the first ISEC organised in Europe since 2018). Finally, it has facilitated grant capture, including NERC funding to Fowler, and new interdisciplinary research addressing the Covid-19 pandemic (Wells and Lurgi), in collaboration with researchers from Medicine, Mathematics and Physics.

A newly completed **£200K zebrafish facility** and multi-omics facility using fish as a model for human disease and pharmacology studies has expanded collaboration with the College of Medicine (Table 3.2).

Collaborations with the physical and engineering sciences have been enhanced by our new **£1.3M research vessel Mary Anning**, which supports research informing decisions about the impact of proposed renewable marine energy installations, and coastal wave dynamics and coastline protection provided by seagrass and salt marshes. Basic and applied interdisciplinary research in nearshore hydrodynamics and coastal ecology is further enhanced by access to the 30m **experimental wave flume** of the SU Coastal Engineering Laboratory (Table 3.3). Further interdisciplinary collaborations are enhanced through the new **(€0.5M) wind tunnel** facility in Biosciences, designed to quantify the power output in vertebrate flight in collaboration with aeronautical engineers, and the secondment of a Computer Scientist for hardware and

software development for animal-attached tags in association with the biologging **Visualisation Lab**.

1.6. Open Research

SU has an Open Access deposit policy (2015), which requires all published research outputs to be deposited in the institutional Research Information System (RIS), which feeds the repository, Cronfa, with an Open Access copy of each full-text article. Biosciences has a **0% Non-compliant output submission** (REF 2), as defined by the REF-2021 guidelines. The Science Research Hub and central library provide support to researchers with Open Access requirements and sharing compliance for UKRI funding. Open Research is a priority for Biosciences and we are leading initiatives with a dedicated data manager developing postgreSQL databases for sharing research data, internally and externally, including with regulatory government agencies and industries. Examples include a new fish tracking database across the River Tawe and Swansea Bay, and one for passive acoustic data on cetaceans along the Welsh coast, both shared with academic and non-academic partners for impact assessment of marine installations and fishery management.

1.7. Research integrity

Biosciences has played a leading role in the development of the SU **Research & Ethics Governance Framework Policy 2015**. Biosciences staff developed and deliver training courses for all SU PGR students on 'Ethics and Research Governance' and 'Ethics and animals', run 4 times per year since 2017. We also lead (Garcia de Leaniz) the **College of Science Ethics Committee** (with a dedicated website and departmental sub-committees), and key contributors (6 Bioscience members) to the University's **Animal Welfare and Ethics Review Body (AWERB)**, responsible for the implementation of the Animals (Scientific Procedures) Act and ARRIVE guidelines (Animal Research: Reporting of In Vivo Experiments), as well as elevation of relevant human-related research to the NHS ethics screening level. Furthermore, Biosciences staff are members of the Animal Welfare Research Network (AWRN). Garcia de Leaniz and Börger (Deputy Director) were founding members in 2016 of SU's cross-disciplinary **Research Institute for Ethics & Law** (see REF5a). Biosciences developed an innovative **online ethics evaluation system** which allows ethical scrutiny of all research done in Biosciences, including 200+ student projects each year. This system has been working successfully for 4 years and has been implemented by other departments across SU. Finally Biosciences also achieves national impact, e.g., Wilson as a member of the **Special Methods Tagging Panel**, which regulates the tagging of birds within the UK; a responsibility devolved from the Home Office.

2. People

2.1. Changes since REF 2014 and investment in people:

Since REF2014, the Biosciences recruitment strategy has been to invest in excellent research aligned with national and international priorities within our 4 Research Themes. Specifically, we have increased critical mass through (i) the appointment of early career staff (36% of new appointments) and (ii) attracting outstanding research fellows, which has enabled us to grow a complementary research base within our core research themes. We have attracted 7 external Independent Research Fellows, 3 of whom have been awarded permanent positions. We have also provided strong support for internal candidates applying for fellowships. Overall, 23 new permanent staff were appointed in the REF period, 17 of which were REF Category A staff.

Biosciences' recruitment strategy is committed to equality in line with our Athena Swan agenda, for which the Department holds a Bronze award. We have actively sought workplace equality by explicitly encouraging applications from underrepresented groups in our recruitment advertising, by making all selection panels gender balanced by providing training on unconscious bias and by including consideration of career breaks in the selection process. This strategy has increase female permanent members of staff, from 20% in 2013/2014 to 41% by July 2020, while maintaining the percentage of BAME staff (20%). It has also increased success in carer progression for female staff, for whom permanent positions grade 8 and above have grown from 12% in 2014/15 to 36% in 2019/20 (Table 2.1).

Table 2.1 Successful application for promotion during this REF period by gender and ethnicity (some promotions correspond to the same person in different years).

Successful Promotion Applications - Biosciences

2014/15-2019/20

Level	Total	Gender		Ethnicity		
		Male	Female	White	BAME	Not disclosed
Senior Lecturer	**15**	7	8	13	0	2
Associate Professor	**11**	5	6	9	1	1
Professor	**6**	3	3	5	1	0
Total	**32**	**15**	**17**	**27**	**2**	**3**

New lecturers are appointed with a 3-year probationary period and a mentoring system pairs them with senior staff members who provide guidance on different aspects of their role such as research grant applications, teaching practice and administration. Research Fellows are granted individual office space, access to laboratories and facilities, supervision of research students and support to apply for research funding. To enhance career progression, specific support is provided for **all Early Career researchers**, including:

- **Reduced teaching and administrative loads** during their first year to allow them to establish as independent researchers. Administrative responsibilities start 6-12 months following appointment, increasing in responsibility with length of service. They move to a half teaching load in the second academic year and full load by year 3.
- **Start-up funding** for travel and/or equipment according to their research needs. Priority is given in competitive applications for internal funding and PhD allocation.
- **Leadership opportunities** such as chairing Research Theme meetings or the Athena Swan Self-Assessment Team (SAT), providing training in leadership and administration.

Our **Professional Development Reviews (PDR**, see Ref 5a**)** include two annual face-to-face line manager meetings to support career development, remove barriers and acknowledge success. The PDR also provides the opportunity to request a change in career pathway and/or apply for promotion, for which there are regular workshops and a specific mentorship programme.

2.2. Support for Research Staff:

Swansea University demonstrates its ongoing commitment to the implementation of the **Concordat to Support the Career Development of Researchers** by publicly reporting against Concordat action plans, and we have continuously held the European Commission's **HR Excellence in Research Award** since 2010 (REF5a).

Postdoctoral researchers are an important component of our Department (currently 29). Each researcher is assigned a mentor and their career progression is supported by the PDR system. Representatives of the research staff participate on committees including the Athena Swan (SAT), which ensures that their career progression opportunities are aligned with the Concordat. During this REF period, 9 fixed-term staff contracts have been moved to open-ended contracts after 4 years of continuous employment (linking with the Concordat) and an internal list of redeployment opportunities has been created to enhance research staff retention. Research staff attend training and networking events (e.g., Welsh Crucible programme for leadership development with particular emphasis on interdisciplinarity, attended by 1-3 ECRs each year during the reporting period). They receive institutional support to write fellowship applications through the new Florence Mockeridge Fellowship Group, currently attended by 4 researchers from Biosciences, where they receive eight months of training and development. Research staff attend staff meetings, supervise research students, attend and contribute to seminars, and organise Research Theme meetings. Several individual Fellows/postdoctoral researchers successfully progressed to permanent research/academic positions (**Table 2.2**).

Table 2.2 Examples of destinations of postdoctoral researchers after finishing their contracts in Swansea in the REF period

Position	Destination
Lecturer/Assistant professor	Exeter University (UK), Stellenbosch University (South Africa), University of Sydney (Australia), Lafayette College (US), Solent University (UK), University of Perpignan (France), Swansea University
Researcher/Fellow	Swedish University of Agricultural Sciences, Aarhus University (Denmark), Max Planck Institute (Germany) (x2), River Restoration Centre (UK), CEFAS (UK), NRW (UK), University of La Laguna (Spain), Autonomous University of Mexico (Mexico), Swansea University (x4)

An annual Departmental Research Budget covers maintenance of facilities, a £400 stipend to all self-funded PhD students and annual incentive awards to academics, used mainly to attend conferences or field work. For staff involved in research and teaching, access to **research-only time** is facilitated through the organisation of terms with reduced teaching and administration loads.

2.3. Supporting research students:

Biosciences has a vibrant student research community which has grown over the last 4 years, consisting of 93 PhD students (45 current) funded by BBSRC, EU (Interreg, MSCA, ERC programmes/College of science), KESS ESF under the Knowledge Economy Skills Scholarships scheme), Sêr Cymru/HEFCW, King Abdullah University, industrial sponsors (e.g., Ocean Matters, 360 Aquaculture) and the Science without Borders Programme of the Brazilian

Government. The Department is (since 2019) an Associate Partner for the GW5-led South West Biosciences BBSRC Doctoral Training Programme (DTP).

Biosciences has a strong commitment to **internationalisation** in terms of research students and during this period has launched several joint PhD programmes with the Universities of Texas and Grenoble (2017) and Cape Town (2018). We have been awarded **two Marie-Sklodoswska Curie Innovative Training Networks, both as coordinators**: AQUAINVAD-ED (2015-2019) -£2M, funding 8 PhD students (3 in Biosciences) and MIX-IT-IN (2017-2021) -£2.5M, funding 11 PhD students (2 in Biosciences).

Biosciences students enrol in the College of Science Doctoral Training Centre (DTC), attend central and departmental training courses (including statistics, R programming, experimental design, communication and research ethics), and organise a very popular postgraduate seminar series, the 'Wallace Coffee Talks', with 56 speakers over the last three years. Biosciences PhD students also co-organise Research Theme regular meetings. Students' progress is annually monitored by an internal panel and progression is approved by the SU Progression Board based on reports from the internal panels and supervisory team, recorded monthly through a central Research Monitoring System. This rigorous procedure has resulted in 48 PhDs awarded within the period of their candidature between 2013/2014 and 2019/2020. During the assessment period 24 PhD students moved onto postdoctoral and Fellowship positions at HEIs or research institutes in the UK and internationally (e.g., Max Plank Institute, Universities of Oxford, Oklahoma, Guelph, Windsor, Alcala, NHS), academic or senior positions (e.g., lecturers in Saudi Arabia and Iraq, Director of Fisheries in Oman), government bodies (EA, UK councils) or to the private sector as SME founders (UK), senior researchers (UK and Estonia) or medical writers (UK). In addition, 25 to 30 MRes students graduate each year with 1 in 3 having subsequently moved into PhDs.

Research students are represented in the Athena Swan SAT with the same staff **equality and diversity** measures applied to research student recruitment. All students are given training on ethics, health and safety and diversity and equality, including unconscious bias. There is also an active LGBT+ community which organises awareness events. Biosciences is also committed to the Race Equality Charter and has actively supported the Black Lives Matter movement, committing to the revision of teaching and learning materials, integration of discussion about racism and discrimination in tutorials and revision of library materials starting 2020.

The wellbeing and progress of postgraduate research students, particularly those in their last year, has been prioritised in the **COVID 19 response** of the Department. During lockdown regular ad-hoc meetings were organised with supervisors to reduce the impact of the interruption of activities. For the re-occupation of laboratories and fieldwork, under the new health and safety measures, we prioritised Postgraduate Research students and their research projects, at least equal to the remainder of the Department research portfolio. For example, the first 22 projects in restart included the work of 14 PGR students.

2.4. Equality and diversity

Our commitment to equality, diversity, and inclusivity accords with SU's Strategic Equality Plan. Swansea University holds an **Athena SWAN Silver Award** (2017), is a **Race Equality Charter** member, and subscribes to **Stonewall's Diversity Champions Programme**, creating an inclusive workplace for LGBTQ+ and non-binary staff and students. Swansea ranks 6th among educational bodies in **Stonewall's Workplace Equality Index**, placing us in the top 50 of all UK employers (REF5a). Bioscience holds its own **Athena SWAN Bronze Award** (2018), and

we are proud to work for a 'Living Wage' employer recognised for its commitment to the **European Charter for Researchers** and **Code of Conduct for Recruitment of Researchers** (see also REF 5a)

As a Department we are working to the Vice Chancellor's goal to a 50:50 gender balance at senior decision-making levels. To do so we have taken active steps in designing an equal and non-biased recruitment process, attracting a more diverse pool of applicants, and improving the promotion process, to achieve equality at all levels. This has led to a sustained improvement in the percentage of female staff members up to professorial level (see details in Section 2.1). Currently female staff members have leadership roles as the Biosciences Academic Research Lead, Biosciences Programme Director, College Director of Teaching and Taught Masters Programme Director. After the Head of Department, the Research Lead and Programme Director are the next most senior decision makers in the department.

In addition, and in line with SU Code of practice, all members of the UoA team with responsibility for decisions on the selection of outputs and impact case studies for this submission undertook mandatory equality training, including specialised courses on equality and diversity and unconscious bias. The submission comprises the one best-quality output from each Category A submitted staff member with the balance made up of the best-quality outputs from the available pool of eligible outputs that includes outputs of former eligible colleagues.

3. Income, infrastructure and facilities

3.1. Research funding

Research grants awarded have risen steadily during the census period, with a total of 129 grants (13-27 per year) and £22.08M awarded (£3.1M yearly average). This represents an average increase of +122% in yearly amount awarded compared to the first census year (range +28% to +767%), with an associated increase in the number of funding bodies (see also section 1.2). The department has also strengthened its links with industry, resulting in research income from the EU (e.g., ALG-AD with 12 other EU partners (2017); €5.5M), and Innovate-UK-BBSRC- NEWTON (e.g., Phycopigments, with Mexico (2016); £435,258).

Grant capture is supported by a comprehensive University framework. The University Research, Engagement & Innovations Services (REIS) support grant capture, horizon

scanning, project management and commercialization activities. The College Research Hub (established in 2015), provides support for bids (***pre-award***, including bid development, demand-management, and quality checks) and administrative support for project delivery (***post-award***, including legal and contract services, IP expertise, and research governance). Through this process, Biosciences' staff submitted 290 bid applications between 2014 and 2020 totalling £84,692,000, that resulted in successful bids amounting to £22,082,305.

The Hub's pre-award assistance includes support for UKRI bids by quality enhancement activities, such as peer-review and mock interviews. We extend this support to non-Swansea researchers seeking fellowships with us.

To support grant applications and collaborations, competitions for internal funding take place annually in the College of Science for **seed funding** (~£40,000/year in total). Although these are open to all staff, early career researchers are given priority. Early career researchers in Biosciences have been particularly successful in securing this funding (e.g., Arbuckle, Fürtbauer, Ortiz-Urquiza, Griffin permanent; Rose, Uren-Webster, O'Rorke fixed-term) resulting in several publications (e.g., Frontiers in Marine Science; Agriculture, Ecosystems and Environment, Journal of Applied Ecology). In terms of **University pump-priming funding,** Biosciences has also attracted funds from the Swansea University Research Grant Enabler (SURGE) (~£15,000 over the last 4 years), and the internal Global Challenges Research Fund (8 awards over the last 2 years, £193,000).

The success of these support mechanisms is evidenced by the increase in funding from different external sources (Section 1), by the high proportion of Research Fellows hosted since 2014, by EU and RCUK/UKRI funding won over the REF period by staff appointed to their first permanent position at SU (4 NERC Standard grants, 1 NERC Urgency grant, 1 MSCA-RISE and 1 ERC Starting grant) and by direct outputs of collaborations started (e.g., Interreg Ireland-Wales Aquacoast project). The growing support for research has also translated into national and international research awards (**Table 3.1**).

Table 3.1 Main awards received by members of staff during this REF period.

Award	Year
Rios Vivos Award	2014
Fellow Learned Society of Wales	2015
Top 50 Power Biologists for conservation	2016
Fellow of Academia Europaea	2018
Humboldt Research Award	2019
PRIMA Fellowship	2019
Ramon Y Cajal Fellowship	2019
Sabbatical Fellowship	2020
Dillwyn Medal	2020
Research Fellowship	2020
Eureka Award for Excellence in Interdisciplinary Scientific Research	2020

Since 2014, SU has invested heavily in pump-priming funds. It established the **Swansea University Research Grant Enabler** (SURGE), which supported many proof-of-concept projects seeking to lever UKRI awards; a **GCRF Funding Scheme**, which helped us win a Royal Society GCRF award; and a **Fellowship Group** that mentors researchers to develop competitive bids. Biosciences has been successful in attracting funds from both SURGE (~£15,000 over the last 4 years), and the internal GCRF Funding (8 awards over the last 2 years, £193,000).

The College has a formal process of grant proposal review beyond the expected UKRI demand management. Experienced colleagues will provide multiple rounds of feedback and guidance, including mock interviews and panel discussions, and ECRs are provided with mentorship support from a senior academic. The Biosciences professoriate also meet regularly to identify actions on how senior members of the team can support others across the department.

The College also facilitates **interdisciplinary research activity** through science cafés, away days, sandpits, festivals of ideas, and substantial seed-corn funding and investment in PhD studentships (>£600K per annum), especially where 50% match-funding is required.

3.2. Research infrastructure

We have invested >**£8.1 million** in a modern research infrastructure to support our research across the four themes and further develop research excellence. Investment in infrastructure and facilities included laboratories equipped with state-of-the-art technology (Table 3.2), a new 18 metre research vessel (Figure 3.1), and animal experimentation facilities (section 3.4).

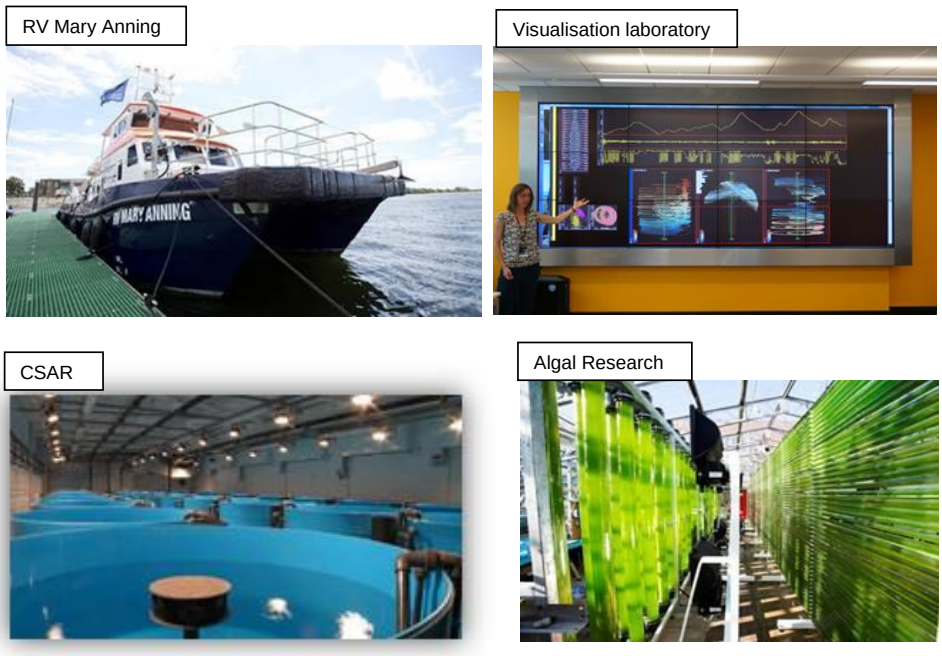

Figure 3.1. Examples of Biosciences research infrastructure

This includes the acquisition of **new specialist equipment,** and the building/refurbishment of **14 laboratories and research facilities** (Table 3.2; Table 3.4). These build upon the £6 million renovation of the Wallace Building and general labs carried out during the previous REF cycle, and complement our other key research infrastructure, such as:

- the Centre for Sustainable Aquatic Research (CSAR) facilities (a 750m^2 controlled environment building containing six wet laboratories, a dry laboratory, a quarantine facility and three dedicated fish laboratories);
- the Animal Movement Visualisation Laboratory, including a high-performance computer and an array of high-definition screens for data visualisation, and an electronics laboratory for the development of animal-attached technologies (funded by a Royal Society Wolfson Laboratory refurbishment grant awarded in the previous REF period);
- 3 aquatic research labs, including specialised facilities for algal, fish, and aquatic ecology research;
- labs for field research in aquatic and terrestrial ecology and biodiversity.

Table 3.2. Research infrastructures - newly built or refurbished for the Biosciences department (August 2013 – August 2020)

Research Structures	Investment	Description
3 new/refurbished Molecular Biology Laboratories	£1,946,877	1 refurbished general use laboratory, 1 new level II/GM facility, 1 new molecular ecology lab (including eDNA facilities).
4 new Controlled Temperature Rooms (UNIGRO)	£1,226,400	1 specialised facilities for aquatic research, 1 terrestrial plant growth room, 2 rooms for aquatic and terrestrial research.
1 refurbished Dissection room	£10,000	1 refurbished dissection room, supporting research in ecology, wildlife epidemiology and OneHealth.
1 new Marine Research Vessel	£1,300,000	The RV Mary Anning (18m, 40-tonne, 25kts top speed, 26 passengers, with dedicated marine laboratory facilities)
1 new Aquaculture building	£424,338	New integrated multi-trophic aquaculture building for sustainable finfish production and high value micro-algae.
1 SmartAqua facility renovation	£2,064,408	1 CRISPR lab (including Nikon SMZ 1270 stereomicroscope), 1 new zebrafish/kilifish facility, 8 new recirculating aquaculture systems (2 ornamentals systems, 2 marine cold/temperate systems, 1 tropical system, 3 model fish racks); 3 LOLIGO fish swim tunnel respirometers.

Furthermore, our researchers have direct access to shared facilities such as the EPSRC UK National Mass Spectrometry Facility and, the £32.5 million Computational Foundry (2018) hosting the Computer Science and Mathematics departments and designed to facilitate interdisciplinary work, and access to Supercomputing Wales resources (Table 3.3), a £16m investment programme in high power computing facilities part-funded by the European Regional Development Fund (ERDF). These facilities are among the UK's best in terms of processing speed and computing power, with access to high-speed network connections and full specialised technical support team. These facilities aid research in the new Centre for Biomathematics and the new Computational Ecology lab, in bioinformatics supporting new staff working in molecular ecology and evolution, and for big data modelling by staff using animal-borne biologging sensor technologies.

Table 3.3. Research infrastructures in the College of Science and the Bay Campus, available and used by Biosciences research staff.

Research Structures	Investment	Description
Key Geography facilities (Wallace Building)	£40,000 (maintenance)	**Isotope-ratio Mass Spectrometry laboratory**; **Microscopy suite** for pollen and micromorphology; **Soil & sediment monitoring equipment** and **secure storage** facilities; **Wildfire temperature monitoring** equipment.
Key Medical School Facilities (Singleton Park Campus)	£2,881,944	**EPSRC UK National Mass Spectrometry Facility (NMSF)**, provides comprehensive broad spectrum analytical services.
Key Engineering Facilities (Bay Campus)	>£10,000,000	**30m experimental wave tank** (coastal erosion research); **EPSRC Advanced Imaging of Materials (AIM) centre (**electron microscopy and x-ray imaging facilities).
Supercomputing Wales	£16,000,000	1 upgraded **supercomputer hub** at Swansea University (high-speed network connections, specialised technical support team, 13,080 processing cores, 1 Petaflop of computing power).

3.3. Support for impact

Our research and innovation career pathway ensures recognition and support for impact-related activities. The University also provides AgorIP (see Ref5a) and RIF funding to support industry-cooperative research activities, particularly around developing impact. The College of Science provides a research fund for all Departments, with one round dedicated to impact-related activities, and Biosciences provides direct IMPACT funding support to give teaching relief for Impact-case study leads. The central REIS office provides impact training workshops to early career researchers with an external trainer and the department ran its own workshop in working with industrial partners. Furthermore, Biosciences has dedicated academic leads for Impact (Rowley and Butt) who, together with our three Innovation Professors (Proffitt, Llewellyn, Rowley), the Impact and Engagement Officer of the CoS, the central University Press Office and Impact and Engagement team in REIS support and advise staff on developing and

maximising the impact from their research. This support, combined with our "Ecology with Impact" strategy around stakeholder collaboration, led to an impact register of 20 case studies Each case study received advice, guidance and feedback on further development; three of these reached maturity and where selected for submission to REF2021.

3.4. Specialist research infrastructure and facilities

The Department has expanded the specialist infrastructure and existing facilities to support the increased number of academic researchers across the 4 Research Themes, for example, the Centre for Sustainable Aquaculture (CSAR) and the animal movement visualisation laboratory (Table 3.4; Table 3.2; see also Section 3.2). Biosciences researchers further benefit also from sustained university-wide investment in new specialist infrastructures and facilities across the two campuses (Table 3.3; REF 5a).

Table 3.4. Biosciences specialist research infrastructures and facilities - newly built or refurbished (August 2013 – August 2020)

Research Structures	Investment	Description
1 new Multi-omics facility	£372,220	Transcriptomics, epigenomics and proteomics analyses equipment enabling multi-omics capabilities from the single cell to whole organism level.
1 new Seagrass laboratory (Seagrass Ocean Rescue)	£50,000	New aquaria facilities for automated processing and mass production of seagrass material for restoration projects.
1 new Applied Aquatic Research & Algal Biotechnology laboratory	£250,000	Fully fitted laboratory facility with specialised analytical equipment (spectrophotometers, light microscopes, HPLC, etc.).
1 new Bird flight wind tunnel & animal husbandry facilities	£500,000	New specialised wind tunnel for measuring flight dynamics and energy expenditure of large birds (gulls, pigeons), with associated aviary to breed and train the experimental birds.

Several of these facilities and infrastructures are unique in the UK, such as the state-of-the-art research vessel and marine laboratory which, can operate in shallow seas and coastal environments as well as offshore. Similarly, the wind tunnel is unique among UK universities in terms of the size of the birds that can be flown.

3.5. Cross-HEI shared or collaborative use of research infrastructure

Many external researchers use Swansea Biosciences' unique facilities such as the Visualisation Suite for animal movement data and the CSAR aquaculture facilities. Thanks to the international partnerships of SU with Grenoble University and the University of Texas at Austin (REF5a), researchers from Biosciences have accessed resources and facilities from the Laboratory for Alpine Ecology (LECA), including long-term field sites and a research laboratory in the French Alps, which has led to collaborations including funding for three co-supervised PhD students and a partnership in a successful grant award by the French ANR national research funding body. Biosciences researchers use other external UK and overseas research infrastructure and facilities, including the sequencing, proteomics and bioinformatics facilities

JGI and EMSL in the USA, and the NERC sequencing facilities at Liverpool (UK); the high throughput sequencing facilities at Cardiff University and the Sanger Sequencing lab at Aberystwyth; the state-of-the-art facilities at Harvard for sequencing ancient DNA; and the isotope facilities at the CSIR in Pretoria, South Africa.

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

Collaboration, internationalisation and interdisciplinary research are at the core of our activity. This has been strengthened over this REF period by the collaborative agreements with the Universities of Texas and Grenoble, our joint doctoral venture with the University of Cape Town, joining the SWBio BBSRC DTP as associate members, and Erasmus agreements with EU-based universities (La Laguna and Vigo in Spain, Heraklion in Crete). Biosciences' links with environment, agriculture and aquaculture-related industry and government agencies at national and international levels have resulted in both advisory and collaborative work (***Tables 4.1-4.4***).

4.1. Collaboration

Biosciences runs a very successful lunchtime **seminar series** which over the last 5 years has hosted 92 speakers from 16 different countries and 5 continents, of which 50% were women (from postdocs to Professors). The seminars are held every two weeks and are widely attended by members of staff, research students and undergraduates, and have initiated many new collaborations. The College of Science opened the **International Visitor Scheme** competition in 2019, with funds to invite international distinguished guests to give public and internal talks and to establish new collaborations. Biosciences secured funds to host Professor Justin O'Riain from the University of Cape Town and Professor Eric Pianka from the University of Texas. The successful nature of our collaborations is evidenced by **69% of our publications including an international collaboration**, and 17% with (only) national collaboration.

Researchers working on **Invasive Species** provide guidance at UK and international levels on the control of the highly invasive Japanese knotweed and Himalayan Balsam, as well as some of the 100 worst aquatic invasive species world-wide including rainbow trout, topmouth gudgeon, zebra mussel, signal crayfish . The impact of this work encompasses local action (through invasive eradication or control initiatives and creation of a dedicated SME), and international initiatives such as a horizon scanning of potential invaders and updating the European Alien Species Information Network.

Key **Marine Conservation** work focuses on policy, governance and management for coral reefs and conservation strategies for seagrass and sea-turtles in collaboration with national and international government agencies and NGOs (WWF, Indo-Pacific Wildlife Conservation Society, Great Barrier Marine Park Authority). For this, members of the Department are part of national and international advisory groups.

Conservation research on **terrestrial and freshwater ecosystems** has impacted international guidelines such as the IPBES Global Assessment Report on Biodiversity and Ecosystem Services, CITES Inspection Manual for Commercial Reptile Breeding, and the Tasmanian Devil Programme in Australia. Members of the Department advised international organisations on further wildlife conservation, for example identifying, mapping and quantifying impacts from instream infrastructure and identifying conservation priorities for freshwater ecosystems.

Biosciences interacts with the Public Health Laboratories at Singleton Hospital next to the Singleton Park campus around teaching and research into zoonotic diseases, formalised through the award of an Honorary Professorship in Biosciences to Professor Edward Guy, Lead

of the Toxoplasma Reference Unit at Public Health Wales. In February 2017, NRW established and commissioned its new National Analytical Laboratory (40+ staff members), adjacent to the Biosciences Department, which has facilitated close working relationships, support, and access to equipment, with NRW staff increasingly integrated into Biosciences research programmes and directly supporting research applications. We achieve further collaboration and support from NRW at its aquaculture and hatchery facility on the river Cynrig in the Brecon Beacons, where we have access to facilities and staff to support aquaculture and fresh water aquatic research. Our collaboration with NRW is further developed through an Honorary Professorship in Biosciences to Professor Kathryn Monk, Principal Advisor for Science at NRW. From 2018, we have been developing a close working relationship with the National Museum of Wales and its natural sciences teams, and the National Botanic Gardens Wales which has resulted in agreements to develop habitat restoration projects at sites in South and North Wales. Biosciences received Knowledge Exchange Economy Skills Scholarships (KESS), funded through the European Social Fund for 11 PhD and 10 MRes students, to develop collaborative projects with external companies. Companies provide cash contributions and in-kind support; 20 companies participated, contributing £160,600.

Industry

Research and Innovation-focused staff members collaborate with industrial partners on diverse projects including aquaculture, algal biotechnology, biocontrol, conservation and invasive species (***Table 4.1***). The Centre for Sustainable Aquaculture (CSAR) is an important resource in our collaborations with industry and has facilitated 15 large Research & Development projects since 2014 on sustainable fish farming and algal culture. CSAR won the Development Bank of Wales **award for Outstanding Impact on Industry, Commerce and Innovation** (2018) and was Highly Commended in the Leadership for the Future (Sustainability) section for the Leading Wales Awards 2019. Its work on developing cleaner fish as an alternative for antibiotics for the salmon industry has resulted in more than £2M funding from several national and international companies (***Table 4.1***). In addition to the industrial impact, members of the Department are part of the Welsh Advisory Committee for Aquaculture and have advised the Scottish Government on discards policy for shellfish species.

Collaborative research into novel biocontrol products for agricultural pests has resulted in 2 patents filed in the REF period, both have been licenced from the University by the collaborating business partner Certis Europe and are progressing towards registration and commercialisation (further details in impact case study).

Table 4.1. Collaboration with industry and government

Activity	**Collaborators**
Guidance on control of invasive Japanese knotweed	Spin-off company (Advanced Invasives Ltd.)
Guidance on control of invasive Himalayan balsam	Bridgend County & Borough Council
Distribution and control of aquatic invasive species (signal crayfish, topmouth gudgeon)	EA, NRW, European Alien Species Information Network
Distribution and control invasive brown trout in the Falklands/impact on endemics	Falkands Government, GB Non-native species secretariat
Advice on coral reefs conservation in the Indo-Pacific area	Australian Research Council Centre of Excellence for Coral Reef Studies

Working group on Periodically Harvested Closures	Wildlife Conservation Society, University of Perpignan/CRIOBE, University of Western Australia, California Polytechnic University, The Nature Conservancy
Advice on status, restoration and impacts on seagrass	NRW, Natural England, SNH
Advice on marine conservation to coastal communities and local government stakeholders	Great barrier Marine Park Authority Marine Monitoring programme (GBRMPA), Wakatobi National Park (Indonesia), Guimeras Island (Philippines)
Sea turtle conservation action and management	St Eustatius National Parks, British Indian Ocean Territory (BIOT) Administration, United States Navy
Guidelines for Inspection Manual for use in Commercial Reptile Breeding Facilities in Southeast Asia	CITES
Advice on Tasmanian devil extinction risk due to devil facial tumour disease	Tasmanian Devil Programme in Australia
Fire Influence on Regional and Global Environments Experiment	NOAA, NASA
International Advisor for Steering Committee and joint lead for the Saprotrophic Agaricomycetes Sequencing Programme	US Department of Energy Joint Genome Institute
Advice on impacts from instream infrastructure and conservation priorities for freshwater ecosystems	EA, Wildlife Conservation Society Canada, The Nature Conservancy – Michigan, French National Agency for Biodiversity, Wisconsin Department of Natural Resources and United States Fish and Wildlife Service
Community engagement with freshwater ecosystems under Global Changes	James Cook University
Baboon-human conflict and coexistence projects related to bark stripping behaviour.	SAPPI Forests (South Africa)
Advice on Aquaculture strategies	Welsh Advisory Committee for Aquaculture
Lumpfish as an alternative for sea-lice control in salmon farming	MOWI, Ocean Matters, The Cleaner Fish company
Advice on fisheries discards of *Nephrops norvegicus* (langoustines).	Scottish Government
Patents for molluscicides, nematicides and mosquito repellents	Certis Europe BV, Rentokil Initial, Lisk & Jone, Syngenta, Puffin produce, CropIQ, Tilhill, Sentomol, EcoVid, Maelor Forest Nurseries, Hektas, Bioglobal, Phytoquest
Support for academic-industry in developing low-carbon economy in Wales (SEACAMS)	Bangor University, Aberystwyth University and SMEs
IUCN Primate Specialist Group	University of Cape Town

4.2 Membership and contribution to academic and non-academic bodies

Permanent academics at Biosciences have participated in national and international advisory boards, review panels and editorial boards during this REF period.

They act as editorial board members of **29 peer review journals** (including interdisciplinary and leading disciplinary journals such as Proceedings of the Royal Society B, eLife, Frontiers in Environmental Science, Methods in Ecology and Evolution, Frontiers in Genetics, Frontiers in Microbiology, BMC Evolutionary Biology, Bioresource Technology) and belong to **33 national and international advisory boards and research award committees** (16 national and 17 international)**.** These include *nationally* UK-wide and Welsh advisory boards and committees at the academic and government level including NERC peer-review panel, British Council Newton Prize Expert Panel Reviewer. Five staff are members of the NERC peer-review panel, including two Core members and one is member of the BBSRC Follow-on Funding Committee. *Internationally*, a large part of the committee and advisory work (26 boards or committee memberships) relates to conservation of marine and freshwater ecosystems both at academic and government levels (e.g., Convention on Biological Diversity, Society for Conservation Biology-Freshwater Working Group, British Indian Ocean Territory MPA Expert Committee, Nordic Centre of Excellence Bioeconomy).

During this period, Biosciences researchers have organised or co-organised **20** national or international conferences (examples in ***Table 4.2***) and have delivered **40** Keynote/Plenary lectures and **142** invited talks in different conferences/forums. Conferences and workshops covered most of the research areas of the Department including biopesticides, invasive species, marine ecosystem modelling, conservation biology or welfare and behaviour (***Table 4.2***).

Table 4.2 Conference organisation

Conference title	Year
2nd Symposium in Plant Biomass Conversion by Fungi (Netherlands)	2017
Workshop on Basidiomycete Post-genomic Research, USA Genetics Society 29th Fungal Genetics Conference (USA)	2017
International Congress for Conservation Biology (Colombia & France)	2017, 2019
Advances in Marine Ecosystem Modelling Research (Plymouth)	2017, 2020
Aquatic Invasive Species management session (NEOBIOTA) (Dublin)	2018
Symposium on Stream Connectivity, American Fisheries Society Conference, Tampa (US)	2018
European Congress for Conservation Biology (Finland)	2018
Crossing the Palaeontology-Ecology Gap (Leeds-UK, Germany)	2018, 2020
International Biopesticide Summit (Swansea)	2019
1st International Symposium on Welfare in Aquaculture (Swansea)	2019
1st Annual Conference of Environment Platform Wales (EPW)	2019

4.3 Responsiveness to national and international priorities and initiatives

Over this REF period, Biosciences staff have responded to numerous national and international initiatives, mainly related to conservation and management of wild animal populations, human-wildlife conflict, invasive species management, sustainable natural products, poverty alleviation and education.

These include the search for evidence-based solutions to **human-wildlife conflicts** in South Africa in cooperation with diverse stakeholder groups and policy makers. Published articles have been used by local government (City of Cape Town) to improve baboon management plans and policy. This research led to the development of "arguably the most successful example of mitigating human-wildlife conflict on the urban edge" (Institute for Communities and Wildlife in Africa [iCWild] Director).

The results of the H2020 AMBER project which tackled the EC priority of river connectivity, summarised in 3 policy briefs, **informed** one of the **EC Biodiversity Strategy Targets** (25,000 km free-flowing rivers by 2030). Research into the ecological consequences of the **UK's fisheries** discards ban also began in response to the update of the European Commission's Common Fisheries Policy, the 2015 implementation of the Landing Obligations.

From a **socio-economic perspective**, collaboration with the Cabot Institute (Bristol) is revisiting the theory of human urbanisation to improve projections of human settlement changes that affect environmental phenomena (***Table 4.1***). Work with ESPA Sustainable Poverty Alleviation within the Coastal Ecosystem Services project investigates reef and mangrove conservation, merging economics, ecosystem services and socio-economics perspectives.

Members of the Department have also participated in the creation or up-dating of **national and international conservation-related guidelines and actions plans** (***Table 4.3*).** Bioscience staff worked with the Law Society of England and Wales to re-write Conveyancing document guidance on Japanese knotweed in response to a UK Government Science and Technology Committee request. Work on salmon stock assessment was used as evidence to ban salmon stocking in Wales in 2014 (***Table 4.3***).

Table 4.3 Responses to national and international priorities and initiatives

Human-wildlife conflicts, baboon project (Cape Town)
Implementation of the Landing Obligations for Fisheries
ESPA Sustainable Poverty Alleviation from Coastal Ecosystem Services
Global Biodiversity Outlook and Technical Report Convention on Biological Diversity
Essential Ocean Variables (Seagrass and macroalgae) initiative
Global Ocean Observing System (GOOS)
Biodiversity Action Plans for the British Indian Ocean Territory
NRW-Welsh government salmon stocking policy
PCP-PIRE (Panama Canal Project, Partnerships In Research and Education)
Living With Environmental Change (LWEC) initiative in Tree Health and Plant Biosecurity
UN GRID-Arendal global synthesis report on seagrass ecosystems

4.4 Contribution to economy and society

Economy

An important part of our research is linked to economy and society. For example, SEACAMS 2 is a strategic priority that **integrates research and industrial opportunities to develop the low-carbon economy and expand the coastal and marine sectors in Wales**. SEACAMS is a partnership between Welsh Universities. Through SEACAMS, Biosciences is providing support to 35 SMEs in diverse projects, for example aiming to increase biological activity in sea defences, develop alternative heating sources using the sea or non-destructive methods to scan the health of marine mammals.

Similarly, SMARTAQUA is a large project (£1.4M) funded by WEFO-ERDF that **supports small business** working on non-food aquaculture (cleaner fish, aquarium fish, aquafeeds and laboratory fish), by creating a network of researchers, aquaculture boards and multinational business to support existing and novel initiatives. It has attracted over 90 novel interactions with business. Our researchers are also leading the ARCH-UK initiative funded by BBSRC, a **multi-stakeholder** aquaculture network for the UK whose main aim is to highlight aquaculture research to funders (UKRI) and facilitate knowledge exchange between the aquaculture industry and academia. Finally, we are furthering the understanding of the marine resources in the Irish and Celtic Seas, with a view to **socio-economic** development through BLUEFISH; an INTERREG Ireland Wales Territorial Co-operation Operation.

At international level, our collaboration with the **agri-forest industry** in relation to biopesticides and the natural products sectors has resulted in **patents** for molluscicides, nematicides and mosquito repellents in collaboration with large companies (Certis Europe BV, Rentokil Initial, Lisk & Jone, Syngenta, Puffin produce and CropIQ). The impact of this work involves many other industry stakeholders representing the supply chain (e.g. Tilhill, Sentomol, EcoVid, Maelor Forest Nurseries, Hektas, Bioglobal, Phytoquest) (REF Impact case).

Society

Our researchers are particularly committed to **communicating science** to the public through festivals, (20 over the REF period including British Science Festival, the Cheltenham and the Leeds Science Festival, and the Green man festival), Apps and the media. In just over half the REF period, our permanent staff featured in >1200 items of media coverage (online, print, TV and radio) in 65 countries.

We help organize the **Swansea Science Festival**; the largest free festival of its kind in Wales, which had over 9000 attendees in its first year. **Citizen science** initiatives include the use of a smartphone app (Barrier Tracker, developed under the H2020 AMBER project) to map all the river barriers in Europe for the first time. **Barrier Tracker was used by 1,400 citizens helping to identify more than 6000 barriers in Europe**. It was promoted by 38 media articles (e.g. BBC international, BBC Wales, The Observer) which shaped public opinion towards the effects of river obstacles. For example, citizen pressure, with the support of AMBER partners, resulted in plans for the construction of a large dam in the River Nalon being abandoned (presa de Caleao, Asturias, Spain) in 2019. The charity Project Seagrass has also developed a global citizen science project (SeagrassSpotter.org), to engage users with seagrass conservation initiatives, including the Global Seagrass Bioblitz (2019). The interdisciplinary nature and social impact of our research is also reflected in the collaboration with artists, bringing science and art

together to **engage different communities** (including schools) about the surrounding natural environments, particularly freshwaters.

Biosciences has a **strong societal and economic impact** at national and international levels, spanning support for small businesses and collaboration with large international companies, to dissemination, training and involvement with different sectors of the public (***Table 4.1***).