Institution: University of Sussex

Unit of Assessment: UoA 10 Mathematical Sciences

1. OVERVIEW

The Department of Mathematics at the University of Sussex operates within the School of Mathematical and Physical Sciences (MPS), alongside Physics and Astronomy. The Department currently comprises 22 permanent faculty members, an increase of 9 full-time equivalents since RAE 2008. New recruitment has been at all career stages. Outputs from 20 have been returned.

Staff are loosely grouped in three research themes: Analysis and Partial Differential Equations (APDE), 11 FTE; Mathematics Applied to Biology (MAB), 6 FTE; and Numerical Analysis and Scientific Computing (NASC), 5 FTE, with many working at the interfaces.

2. RESEARCH STRATEGY

The mathematical areas in which we specialise build on our long-established strengths. These areas are partial and ordinary differential equations, and numerical analysis with particular emphasis on biological sciences and medicine. They provide strong potential for socio-economic impact while providing a rich area of important and challenging mathematical problems. These fields allow us to make a significant contribution to the applied area by introducing mathematical techniques that are novel to the field but also return new and challenging problems that push the boundaries and influence the academic agenda of the underlying mathematical discipline.

The strategy articulated in RAE2008 was to ‘develop, maintain and enhance the standing of the research in the existing three themes’ through new appointments, with ‘no plans to introduce a completely new area at this stage’. Interdisciplinary and applied research was to be strengthened with ‘appointments at the interface areas’. We were ‘committed to significantly increase [grant] activity’.

This strategy was successfully implemented and has achieved a vibrant and sustainable faculty base in the three related themes. In Numerical Analysis and Scientific Computing (NASC), the total faculty base remains at six, of whom four are new appointees (Scalas, Düring, Jensen, Makridakis) replacing departures. The Mathematics Applied to Biology group (MAB) has grown from four to five, with two new faculty at the core (Blyuss, Kyrychko), one arrival providing a broader modelling basis (Georgiou), one departure (Broom) and one evolution of primary theme (Giesl to APDE). In the Analysis and Partial Differential Equations theme (APDE), the faculty base has grown from three to eleven (outputs have been returned from nine of these), with two strengthening the core (Melgaard, Cagnetti), three interfacing with NASC (Dashti, Koch, Zarnescu), one with NASC and APDE (Palombaro), one establishing a link to Stochastics (Tsagkarogiannis) and one to MAB (Giesl), strengthening the existing link (via Taheri).

As planned, many faculty work at the interface of these themes (e.g. Tsagkarogiannis, Giesl, Madzvamuse and Düring), with joint publications with others from different groups. Outward-facing interdisciplinary work is also prominent, with publications in both core and interface journals. Three PhD students are jointly funded by Mathematics and either the School of Life Sciences or the Informatics Department. Madzvamuse, in particular, has a wide variety of external collaborations with bioscientists, medics and engineers to model, for example, filaments in the area of cell motility, fluid–structure interaction in arteries, rice blast-fungus diseases or Neutrophil migration during wound-healing. Dashti, Koch and Zarnescu study the analysis of fluid-flow equations while Styles undertakes numerical analysis and implements finite element models for multi-phase fluid flow. Blyuss, Kiss and Kyrychko work at the interface of non-linear dynamics, delay differential equations and stochastics with applications to epidemic dynamics and engineering.

As described in Section 4, our grant income is now (2012–13), about a factor of 4.6 higher than it was in 2008–09 and comes from a diverse range of sources.

Building on this success, we have adapted our strategy by:

- *continuing to grow the research base in our core areas of expertise with an emphasis on capacity-building* – recent appointments have included three Professors (Makridakis, Melgaard and Scalas) who provide leadership, together with a number of extremely promising and energetic early-career researchers (e.g. Cagnetti, Georgiou, Koch, Palombaro, Tsagkarogiannis, Zarnescu). Together these appointees give us the capacity, in particular, to exploit opportunities for large grants – e.g. through EU Horizon 2020;

- *gradually expanding the boundaries of these research groups by identifying strategic areas for development into new core and new applied areas* – the appointment of Scalas, Georgiou and Tsagkarogiannis enables us to develop a new research theme in Probability and Stochastic Processes which will enable us to tackle new problems within existing applications, thus exploiting current networks. We plan for this to be a viable group in its own right by the next REF (requiring approximately two or three new appointments). This will have strong synergy with existing activity (e.g. the semi-Markov extension of epidemiological models of Düring and MAB) and through the study of stochastic (partial) differential equations (APDE and NASC);

- *proactively enhancing the collaboration with external groups in other Schools in the University and beyond* – the NASC and MAB groups will seek to expand their activities in scientific computing in collaboration with the Brighton and Sussex Medical School. The MAB group will strengthen existing links with the Biochemistry and Molecular Biology subject group in the School of Life Sciences; Scalas is developing collaborations on financial modelling with the School of Business, Management and Economics. To enhance these interactions and link to a much broader field of applications though front-line research in other Schools, the Department is leading an ambitious plan to establish a new Interdisciplinary University Research Centre in Scientific Computing and Modelling. This would provide new research staff and administrative and technical infrastructure, exploiting the University's new strategic initiative 'Sussex Research' which will enable interdisciplinary research programmes through major investments (£1–3M) in research capacity; and

- *enhancing our facilities, environment and support to increase capacity* – enhancements to the support are described in Section 3 and the facilities (notably in High Performance Computing) are described in Section 4.

Building on our success since RAE 2008, the Department's vision for the next five years is thus to firmly establish itself as an energetic, modern and leading research environment with the capacity to make substantive international contributions to mathematics and its application.

3. PEOPLE

Staffing strategy

Realising our overall research vision is dependent on a successful staffing strategy – the recruitment, support and retention of high-quality staff in the selected fields outlined in Section 2.

A significant number of new appointments have been made, with 14 permanent members of faculty having been recruited since 2008 (nine Lecturers, two Senior Lecturers and three Professors). Individuals have been appointed who enhance the Department's three research themes in such a way that they have a strong capacity to interact not only within their themes, but also within an interdisciplinary context.

We recruited individuals whose research provided enhanced opportunities for socio-economic

impact while maintaining mathematical excellence and rigour. All new appointments have connections with established research themes, but add the potential to expand into new areas; they thus benefit from the existing research environment as well as opening up new pathways for the future expansion and diversification of our research portfolio.

It is the goal of the Departmental staffing policy to create an environment that allows all members of staff to carry out the aims set out in Section 2 above. To achieve this the Department has three main staffing priorities:

- ***The retention of the best staff***

  Staff retention is important in developing a strongly interactive research base and providing the stability for higher-capacity research. Prior to RAE 2008, we had some difficulties with retention and have developed strategies to address this. The Department has developed a more collegial, nurturing and professional research environment (see below on staff development). The turnover of staff is now healthy, with only five departures since 2008, four of them to professorial positions with destinations such as Oxford and UCL. Since 2010, the Department has lost only one member of senior staff to another HE institution.

- ***Senior appointments***

  These have been especially important for their direct impact on our strategic aims. Three Chair appointments have been made and the new Professoriate forms the core of the Department's Research Strategy Committee. These appointments have been critical in enhancing the Department's internal research leadership capacities and external research profile. The three were recruited from positions at the University of Crete, l'Università del Piemonte Orientale, Italy and Uppsala University, Sweden.

- ***Lecturer recruitment***

  Lecturer recruitment is crucial to enhance our capacity. Since 2010, seven faculty have been recruited at Lecturer level, one of whom has been promoted to a Senior Lectureship. Lecturers have been recruited from lectureships or Assistant Professorships at the University of Crete, the University of L'Aquila (Italy), the University of Utah (USA) and the Universities of Bristol and Durham, and postdoctoral or fellowship positions at Vienna University of Technology and the universities of Warwick, Oxford and Bristol.

In terms of both seniority and areas of expertise, the Department now has a well-balanced staff profile. Moreover, this staff profile is sustainable: no retirements are anticipated during 2014–19, and the Department's Professoriate and Readers provide a strong leadership team throughout this period.

Staff development

Improvement in our staff development practices has led to the creation of a highly professional and also supportive research environment in the Department. Key elements now include the following, which will also underpin our future practice:

- ***Prioritising time for research***

  The Department actively seeks to maximise the time available for effective research. By optimising the structure and teaching of the degree programme, the Department has given faculty the opportunity to concentrate their teaching in one or other of the University's two teaching terms, to create significant continuous periods for dedicated research. In the last two years, for example, Mathematics faculty have taken fellowships at the ETH in Zurich, the Newton Institute in Cambridge and the University of New South Wales in Sydney. The typical teaching load is two courses per year, but members of staff with important administrative duties or large projects typically receive a rebate of one course.

- ***Appraisal and mentoring***

  All faculty and post-doctoral researchers are appraised annually by trained senior mathematics colleagues or the Head of School. At appraisal meetings, formal objectives are established and monitored the following year and, in addition, appraisers act as mentors, providing supportive advice during the course of the year. Early-career researchers and newly-appointed faculty receive particularly intensive support from mentors – e.g. providing guidance on approaches to supervision and research funding. New faculty also have reduced teaching and administrative loads during their probation period. Typically this means that new members of staff are not required to undertake lecturing duties in their first semester and no administrative duties in their full first year. Exceptions to this are made when the staff member concerned volunteers for such activities. In any case, the overall Departmental load for new arrivals is kept well below half that of established members of staff. New staff members are also equipped with a substantial start-up grant for research visits, conferences, equipment and one School-funded PhD student. Application for their research grants is strongly supported through formal peer-review processes.

- ***Training***

  The University Staff Development Unit runs a wide range of courses including, for example, courses on applying for grants, supervising graduate students and managing research groups.

- ***Financial support***

  The Head of the Mathematics Department has access to a discretionary account to cover some research costs, e.g. conference travel. Each individual also has a Devolved Budget, awarded in proportion to contribution income from research grants, to be spent on their own research initiatives.

As evidence of healthy staff development, seven faculty have been promoted internally, two to Readerships and five to Senior Lectureships. All faculty who were at Lecturer or Senior Lecturer level in 2008 have since been promoted.

The Department of Mathematics recognises and values researchers as a key component of its overall strategy to develop and deliver world-class research.

We ensure that researchers are equipped and supported to be adaptable and flexible in the global research environment by providing appropriate mentoring and training, both at Departmental and at University levels. The importance of researchers' personal and career development, and lifelong learning, is clearly recognised and promoted at all stages of their career; individual researchers share the responsibility for and need to pro-actively engage in their own personal and career development and lifelong learning. We also promote diversity and equality in all aspects of the recruitment and career management of researchers by, for example, actively working to attain the Athena SWAN Bronze award (see below).

All postdoctoral research fellows employed in Mathematics after 2008 have progressed to research positions in other academic institutions.

Research students

- ***Graduate programme***

  Many of our PhD students are financed by EPSRC DTG studentships. The School has provided matched funds and this enables the University to provide our School with more PhD students. A few students are self-funded. Our strategy for research students is to recruit high-potential young researchers, whether internal or external, who show evidence of scholarly excellence. We nurture the outstanding internal students through the University's very successful Junior Research Associate (JRA) Scheme, which is a pioneering project that aims to develop future research leaders. It includes a bursary allowing students to undertake a research project in the

summer (in addition to their MMaths project) and encourages talented and ambitious undergraduates to consider a career in research following graduation.

- ***Supervision and support***

  Each PhD student has two supervisors – a main and a second supervisor. Joint supervision across departments is typical for interdisciplinary research projects. The students have weekly meetings with their supervisors, who operate an open-door policy. Progress is monitored with a formal Annual Monitoring process. The University's Doctoral School runs training and professional-development opportunities for doctoral supervisors, which supervisors attend on a regular basis.

- ***Training***

  The University has established a Doctoral School Committee which provides a clear focus of institutional responsibility for doctoral students and early career researchers. The University has been awarded a European Commission HR Excellence in Research badge as a recognition of its good practice in the career development of researchers. Research fellows are encouraged to undertake part or all of this training as part of their personal development.

  The Doctoral School runs a broad training programme for both postgraduate and postdoctoral researchers which maps onto the Vitae Researcher Development Framework. It also provides, amongst other things, a Research Staff Association, funding for Researcher-led Initiatives, and careers advice.

  The Doctoral School delivers a range of professional development workshops – for example, communication, publication, personal effectiveness, teaching in HE, project management, IT training – as well as events dedicated to doctoral researchers; English-language training is offered for international students. At the School level, a fortnightly seminar series takes place in which postgraduate students give lectures on their own research. At the Departmental level, advanced courses are given for research students and there is the opportunity to attend a wide range of relevant MSc modules. Research students also attend the weekly Departmental colloquia given by local or international experts on a wide range of areas in applied mathematics and they participate in local- and national-level postgraduate training events such as the NAIS/DUNE Summer School 2012 in Warwick.

  A highlight of the year is a one-day, School-funded, PGR student-run, postgraduate research conference that displays a range of work from both postgraduate students and postdoctoral researchers within the School.

  Career development for research students is a priority and we have a faculty member with responsibility for PG careers. Students are also strongly encouraged to undertake formal employability and transferable-skills training through participation in focused events organised either by the University or externally and this is monitored in their annual appraisal.

- ***Integration into the School and Department***

  On the initiative of our research students a School PGR Student Committee has been established, chaired by a student representative. It has its own budget for the development of collaborative opportunities amongst doctoral researchers.

Equality and diversity

The University of Sussex has recently received the Bronze Award from the Athena SWAN Charter for its commitment to improving employment practices in recruiting and promoting women to senior positions in STEMM departments. Since RAE 2008, the fraction of women in the Department has risen slightly from 15 to 18 per cent. The University's flexible working policy and procedures allow working parents to request flexible working patterns to enable them to balance their home and

work responsibilities. Staff in MPS have been granted flexibility in their teaching timetables to meet their childcare commitments. All formal meetings and committees of the Department and University are scheduled to take place within core working hours. The University's maternity, paternity and adoption-leave schemes offer significant enhancements over the statutory schemes. Ofsted has rated the University's childcare facilities as 'excellent'. The provision is to be significantly expanded, with a new £2M building due to open in 2014.

4. INCOME, INFRASTRUCTURE AND FACILITIES

Research funding

During the assessment period, the Department has improved its research-income generation by a factor of 4.6. In 2008–09 the annual grant income was £46k with contribution income of £23k while, in 2012–13 the figures were £212k and £112k respectively. This has been achieved even though most of the faculty growth has been recent (with 13–15 faculty for the first five years). Highlights include Kiss, who had a £100k EPSRC grant in 2009, and Madzvamuse and Styles who currently have a £400k EPSRC grant.

We have attracted funding from diverse sources such as the Hausdorff Institute, the Royal Society, the London Mathematical Society, the British Council and International Asset Management Ltd.

We intend to build on this success in the future by further developing interdisciplinary collaborations that will lead to access to a more-varied range of funding bodies, enabled in large part by the recent strategic recruitments.

Research infrastructure

- ***High-performance computing***

  In 2010, MPS and the University jointly purchased a local High-Performance Cluster of which the NASC group, in particular, make use. From 2008–12 the University invested £2.2M in the machine room and standby generator. The total investment in hardware has been around £500k – most recently in 2013, with an MPS investment of £114k in new nodes – and MPS have contributed 75 per cent of the hardware costs in total. The facility now has about 1,800 cores and 450TB of Lustre parallel-file system and 80TB of NFS storage. This is an important component in our strategy for capacity-building for substantial future programmes.

- ***Support for funding applications***

  Research funding applications are coordinated within the School of Mathematical and Physical Sciences by an academic Director of Research and Knowledge Exchange. The University allocates a Research Development Officer who provides administrative support for research-grant applications. All funding applications are subject to formal internal peer review, and unsuccessful grants undergo a post-outcome review to enhance future submissions. These processes have led to significant improvements in grant-application success rates (see above).

- **Start-up support**

  All new faculty have been provided with a generous start-up package. For recent appointments this includes, as a minimum, 1 funded PhD student. The University investment in start-up packages for 2013 appointments in the School of Mathematical and Physical Sciences is around £800k.

- ***Estates infrastructure***

  Since 2008, substantial investments in research infrastructure for the Department of Mathematics have been made. In 2011 the Department was relocated to a central location on campus adjacent to the Department of Physics and Astronomy and in the close proximity to the

other science departments, greatly enhancing the ease of collaboration for interdisciplinary research. Significant building and refurbishment work had been undertaken in the new location. Commitment of the University to the School extends into the future, with a new Strategic Plan 2013–18 committing to a significant – £120M – renewal of the Science Estate.

5. COLLABORATION OR CONTRIBUTION TO THE DISCIPLINE OR RESEARCH BASE

Overview

The Department has an international and energetic faculty consisting of many early-career researchers. Each researcher has given invited talks at international institutions and conferences and served as a referee for the best journals in their area of research. The faculty members are regularly invited to give plenary lectures at international conferences and workshops, and to invitation-only conferences such as the Newton Institute (Düring, Zarnescu), the Mathematics Institute Oberwolfach (Jensen, Koch, Makridakis, Styles), ZIF-Bielefeld, Germany (Scalas) or the Banff International Research Station (Düring, Koch). Individuals have reviewed research grants and research groups funded by overseas research councils. The faculty has also participated in the organisation of many international workshops.

Collaborators

All faculty members maintain a network of national and international collaborators in their areas of expertise. Examples of world-leading international collaborators include J.M. Ball (Oxford), C.M. Elliott (Warwick), C. Kenig (Chicago), P. Maini (Oxford), P. Markowich (Cambridge), A. Stuart (Warwick), E. Suli (Oxford), S. Mueller (Bonn), G. Allaire (Paris), J. Rauch (Michigan) and T. Kaizoji (ICU, Tokyo, Japan).

Examples of invited/plenary lectures at conferences and workshop

These include:

- Dashti – 'Inverse Problems in Science and Engineering' (Isaac Newton Institute) and 'Statistics, Learning and Variational Methods in Imaging' (DAMTP);
- Düring – 'Econophys IV' Kolkata (Kolkata, India);
- Koch – 'Journées EDP' (Port d'Albret, France);
- Makridakis – 'Recent trends in Computational PDEs' (Bombay, India); and
- Scalas – 'Financial Networks and Systemic Risk Analysis' (Kyoto, Japan).

Examples of the organisation of workshops

These include:

- Styles – two 5-day workshops at the Mathematics Institute Oberwolfach;
- Giesl – 'Algorithms for Dynamical Systems and Lyapunov Functions' (Reykjavik);
- Zarnescu – successfully implemented the 3-month research-in-groups programme 'Group Zarnescu' (Hausdorff Institute, Bonn). Two 3-day international conferences have been held at the University of Sussex; and
- Scalas – Workshop on Fractional Calculus, Probability and Non-Local Operators BCAM, Bilbao.

Examples of editorial-board membership/Associate Editorship of journals

These include:

- Madzvamuse is on the editorial board of the journal *In Silico Tissue and Cell Science*;
- Scalas is a member of the editorial boards of the *Journal of Economic Interaction and Coordination*, the *International Journal of Applied Nonlinear Science* and the journal *Fractional Calculus and Applied Analysis*. He is also academic editor of the journal *Advances in Complex Systems* and the open-access journal *PLOS ONE*.