BIOGRAPHICAL MEMOIRS

Michael John Robert Fasham. 29 May 1942 — 7 June 2008

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Elected FRS 2000

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Professor Michael Fasham played a pioneering role in the development of marine ecosystem models for the study of nutrient and carbon cycling in the ocean. He is particularly celebrated for his famous Fasham–Ducklow–McKelvie model, which was the first of its kind to separate new and regenerated forms of nutrient, as well as including microbial recycling pathways. Fasham’s models provided key understanding of the links between primary production, carbon cycling and export (of organic matter from the surface to deep ocean) based on both deep and insightful parameterization inspired by his many collaborations with leading experimental and field biologists of the day, and by his expert use of data for model calibration and validation. He had the ability to see the big picture, linking observation and models to achieve a unified understanding of system dynamics. As well as the direct contributions of his own science, Fasham played a pivotal role in steering the international scientific agenda, notably his leadership of the Joint Global Ocean Flux Study which had the aim of understanding ocean carbon cycling and sinks via the coordination of extensive field programmes, synthesis and modelling. He will be remembered by those who knew him for his openness, enthusiasm and modesty, a man who was fun to know and to work with and who loved the thrill of scientific adventure and discovery.

FAMILY BACKGROUND AND EDUCATION

Michael (Mike) John Robert Fasham was born in Edgware, Middlesex, on 29 May 1942. His father, Ronald Henry Alfred Fasham, was posted to 467 Squadron during World War II, flying Lancaster bombers and completing an operational tour of 35 flights over Germany and France. Ronald had met Mike’s mother, Hazel Grace Day, through their joint love of cycling and the two married in November 1940. Mike and his mother at first lived with her parents in Kingsbury during the war but they later rented a flat in nearby Neasden and eventually moved to Kenton in 1953. Sisters Diane and Jacqueline were born in 1947 and 1958.
Mike attended Wykeham Primary School and was apparently a troublesome boy although his mother, having missed out on the best educational opportunities herself, soon sorted him out. It was during his last two years at Wykeham that Mike was inspired by his teacher, Mr Bodger, to become a scientist and he duly passed his 11-plus scholarship exam in 1953. He then moved on to Kilburn Grammar School in Brondesbury, where he focused on science subjects including physics and chemistry, but not biology (the school’s biology laboratory had been destroyed by a bomb in 1944 and was not rebuilt until 1958). Aside from his studies, Mike blossomed on the sports field, playing rugby for the school’s first XV and running in the Middlesex Schools 100-yard final (although he came last!). His parents bought him a Raleigh bike when he was 13 years old and he spent time cycling with friends throughout the UK, as well as a trip to the Rhine and Moselle valleys at the age of 15 years.

Having passed A-levels in mathematics, applied mathematics, physics and chemistry, Mike enrolled for a degree in physics at Birmingham University in 1960. He took geology as an extra subject because he had been fascinated by the scientific results coming out of the International Geophysical Year (1957–58) that included topics such as geomagnetism, cosmic rays, meteorology and seismology. Mike particularly enjoyed the geology lectures and by now he had set his sights on a career in geophysics. Core physics nevertheless continued to capture his imagination and by the final year he was immersed in subjects such as relativity, quantum mechanics and particle physics. Exam time arrived on his 21st birthday, leaving Mike little energy to down the obligatory eight pints of beer that evening! The award of an upper-second-class honours degree duly followed in 1963.

A choice now presented itself: continue in academia with postgraduate study or get a job in industry and earn some money. After vacillating for a while, Mike joined the fortune-hunting gang. He took up a position with the United Steel Company and, along with two other apprentices, started work in the Operational Research department situated in Cybor House, Broomhill, in January 1964. He was allocated to a project to determine the optimum number of cranes that would minimize delays in the steel melting shop of the Appleby–Frodingham works in Scunthorpe. The work involved using a Ferranti Pegasus computer, a vacuum-tube-based machine with a 4-kilobyte drum store and an internal store of 40 words. This early experience of using computers and writing programs would be invaluable for Mike’s future career. He also developed an interest in statistics at this time, again a skill that would prove useful in future. After four months’ work, Mike concluded that the optimum number of cranes was five, exactly the number that were already in place! The problem solving was enjoyable and Mike soon found himself thinking about returning to an academic research environment to do a postgraduate degree. United Steel would probably have sponsored him to take a masters course in Operational Research but the enduring appeal of geophysics was to win the day. Mike knew that the Geology Department at Birmingham ran an MSc in applied geophysics. Resigning his position at United Steel, he enrolled for a PhD, but taking the MSc course in the first year to obtain a firm grounding in geophysics.

The MSc work consisted of a broad range of lectures on solid Earth geophysics, as well as extra training in statistics. There was also a field project involving a geophysical survey of the Bovey Tracey basin, situated on the eastern edge of Dartmoor. Mike had responsibility for the gravity survey, which entailed driving around with a Worden gravimeter looking for Ordnance Survey benchmarks so that an accurate height could be obtained for each gravity measurement. Interpretation of the results was rather complex but, thanks to his recently acquired programming skills, Mike was able to show that the basin depth was considerably
deeper than had previously been thought (1)*. His PhD, supervised by Professor D. H. Griffiths, entailed researching the geological structure of the Scotia Sea in the Southern Ocean. Mike analysed several magnetic transects that had been made on British Antarctic Survey supply trips between the Falklands, South Georgia, Graham Land and the South Sandwich Islands, characterizing the different anomalies and using multivariate statistical methods to search for geographical patterns. The analysis showed long linear spatial correlations of positive and negative anomalies that, in his final year, Mike was able to explain by using the sea floor spreading theory developed by F. J. Vine (FRS 1974) and D. H. Matthews (FRS 1974) at Cambridge University. As it happened, Mike’s statistical methodology of analysing these data sets was soon rendered obsolete with the advent of navigation via satellite data and he therefore did not write the results up for publication. He was awarded his PhD in 1968. Mike’s one long-lasting regret is that, throughout his career, he never actually managed to visit Antarctica.

During the years he was back in Birmingham, Mike had shared several houses and flats with a variety of friends, some of whom dated back to his undergraduate days. They all worked hard but also somehow managed to find the time and money to enjoy themselves immensely. Partying one evening in August 1967 Mike looked across the room and saw his future wife, Jocelyn (Jos) Hart, who was studying for an MSc in comparative neurosensory physiology and behaviour. A whirlwind romance ensued and the two of them were engaged just three weeks later, much to the amazement of their friends. After a further three months they married, the only drawback being that the bride and groom, having merged their overdrafts, could not afford a honeymoon and so spent the time instead in their flat in Ealing, deciding on whether they had enough money for an Indian takeaway. As always, Mike continued to play rugby and after reaching the dizzy heights of playing for a (minor) Wasps team, as well as the Moseley 2nd team, his later games at Guildford and Godalming Rugby Football Club were thankfully less athletic, but always enjoyable.

At this time, Mike was thinking about what he might do after getting his PhD. Many of his colleagues in the geophysics department had been undertaking geophysical surveys in the Antarctic with teams of dogs but, for whatever reason, Professor Griffiths was not supportive of this avenue and Mike once again left the academic fold, albeit temporarily. Nigel Ridley-Thomas, who had been on Mike’s MSc course, had been appointed head of geophysical surveys at Wimpey Laboratories and offered him a position to develop geophysical computer software. The money was good but Mike soon became disillusioned and unhappy with the new role. The working atmosphere was necessarily very commercial and he missed the freedom of academic life. Furthermore, he and Jos had moved to a flat on Richmond Hill in early 1968 and, although the area was nice, it was beneath the flight path to Heathrow. Mike soon discovered that he had a low tolerance to noise, lying in bed in the morning counting planes passing overhead at three-minute intervals. One weekend, after visiting friends who lived in the peaceful Kentish countryside, Mike realized that they had to leave London. Picking up the Sunday’s Observer, he saw an advertisement for a job in the computer department of the National Institute of Oceanography (NIO) at Wormley (near Godalming, Surrey). In September 1968 Mike and Jos moved into a lovely rented cottage close to Milford station and in the following year they purchased a town house in Hill Road, Godalming. At 26 years of age, Mike had a degree in physics, a PhD in geophysics and a wealth of experience with both

* Numbers in this form refer to the bibliography at the end of the text.
computers and statistical techniques. There was no inkling as yet, however, that his greatest achievements would be in the realm of biological oceanography.

**Oceanography: debut and transition to biology**

Mike started work in the computer group at NIO in September 1968. Computers were new to oceanography at this time and Jim Crease, leader of the group, had successfully persuaded NIO to purchase two mainframe IBM 1800 computers. The first of these was installed aboard the NERC (Natural Environment Research Council) research ship, RRS *Discovery*, for work at sea while the other was located back in the laboratory for post-cruise processing and analysis of data. The IBM was so large (about 2 m in height) that a hole had to be cut in the side of the ship to allow it to be installed on board! Mike’s job was to be responsible for the shipboard system, involving the development of functionality in two main areas, navigation and data processing. Precise navigation involved logging satellite fixes taken with a Magnavox 702 satellite receiver, which, in combination with the dead reckoning position of the ship (based on the ship’s heading from gyro and the two-component electromagnetic log), allowed precise calculation of the ship’s position. The necessary calculations were handled for the first time by the IBM 1800 on Mike’s second cruise, *Discovery* 29, to the Rockall region and the Azores in August to October 1969. The quality of the received satellite signal depended on the ship’s heading and so, to acquire the satellite fix most accurately, Mike would often make his way to the bridge in the middle of the night to convince the Mate to alter the ship’s heading! Computerized data logging of oceanographic measurements on board ship was also highly advantageous. As well as navigation, measurements included Swallow float velocities, CTD (Conductivity, Temperature, Depth) station profiles of temperature and salinity against depth, meteorological observations and bathymetry. Cruises usually lasted at least several weeks. A large boon for the scientists was therefore the production of plots and charts from the computer-held data that both enhanced effective decision making regarding the scientific programme and indicated potential instrument malfunction. Mike’s programming skills were at a premium given the need for efficient use of the disk space available; the IBM 1800 had a core storage capacity of 32 kilobytes with three additional interchangeable disks each with the ‘immense’ (Mike’s own description) capacity of 500 kilobytes. We take computers for granted today, but not only did Mike have to deal with the limited disk space, there was also the ancillary equipment which included a paper tape punch and readers, disk ancillary store, typewriters and plotters.

The shipboard computer group consisted of three: Jim Crease, Mike Fasham and Brian Hinde. There were many *Discovery* cruises and between them they tried to cover them all. Mike participated in seven cruises during the period from 1968 to 1973 and, as he often said, it was fortunate that he did not suffer from seasickness. Two IBM engineers were also seconded to the group for a year and everyone worked long hours. To relax at the end of the day, Mike and Jim would often play a rubber of bridge with the engineers and then go back for some late-night computing for further cognitive entertainment.

All scientists at NIO were encouraged by the Director, G. E. (later Sir George) Deacon FRS, to have a personal research interest to be pursued in addition to assigned duties. Harking back to his university days, Mike’s first thought was to pursue a geophysical topic but he found himself heading in another direction when word got round NIO about his statistical
skills and Margaret Thorrington-Smith, of the Biology Department, asked him to help her to analyse phytoplankton data from the Indian Ocean Expedition of 1964. Dendograms were constructed to organize species into phytohydrographic regions (Thorrington-Smith 1974). Soon afterwards, Mike met Martin Angel, another of the marine biologists and a specialist in ostracods (a group of crustacean zooplankton). Martin had taken part in the 1965 SOND cruise (the name denoting the months September to December during which the cruise took place) to an area southeast of Fuenteventura in the Canary Islands, looking at the biodiversity, vertical distribution and migratory behaviour of animals (zooplankton) in the upper 1000 m of the water column. Faced with an enormous data set describing many species, depth zones and the changing light environment (diel cycle and depth), Martin wanted to go beyond the usual descriptive analysis; the two of them wrote a paper (3) involving extensive analysis of the data using techniques such as factor analysis and cluster analysis. Formally joining the biology department at NIO in 1973, Mike spent the following years working with the biologists using statistical methods in the study of the biogeography of zooplankton in the northeast Atlantic (4–6, 10).

Mike was always one to chip in to the teamwork and hard graft that was required in seagoing scientific expeditions. As well as his own direct contribution, going to sea also gave him a full appreciation of the difficulties involved in making a coordinated suite of physical and biological observations and the errors and uncertainties thereof. Mike wanted to be involved in the biological sampling programme, although also continuing with computing duties using the IBM 1800. Travelling to the equatorial Atlantic on board cruise Discovery 61 in the spring of 1974, he used fluorometers to measure the distribution and patterns of chlorophyll in the ocean. Many cruises were to follow, with Mike continuing the fluorometry work, allowing him to directly study the patchy distribution of plankton in the sea and its relationship to light, nutrients and the physical structures in the upper ocean (7).

Cricket was a passion of Mike’s and he was a regular for many years with the NIO team. Mike’s forte was his style. He fancied himself as the David Gower of the side but, more often than not, ended up wafting his bat at the ball as it went by. On one occasion, there was a cricket match at sea, during cruise Discovery 92 to the Porcupine Sea Bight in 1978. Mike’s birthday happened to take place during the cruise, as did that of his colleague Howard Roe, and the two of them were presented with a cricket bat crafted from planks by the ship’s carpenter inscribed ‘To Fasham and Roe, Discovery Cricketers of the Year 1978’. The match took place on the after deck of the ship and, needless to say, it was not long before the ball disappeared over the side. To Mike’s great delight, years later, he and his son Matthew (co-opted as a demon bowler) played together for the Institute of Oceanographic Sciences (IOS) cricket team, but on dry land where the balls merely disappeared into the undergrowth.

Mike’s ascent and mastery of his new discipline, biological oceanography, took place at remarkable speed. His multifaceted knowledge of physics, biology, statistics and mathematics gave him holistic insight into the interrelations between light, nutrients, physical mixing and the underlying observed patterns of plankton patchiness in space and time. His seagoing continued unabated and, indeed, in 1979 he had the honour of acting as Principal Scientist on cruise Challenger 5/79, the cruise programme involving a study of the developing phase of the phytoplankton spring bloom in the shelf seas to the southwest of the UK. But it was in the theoretical understanding of plankton dynamics that Mike excelled, to the extent that he was already becoming a leading authority in his field. As such, he was invited to write a major review article concerning the theoretical basis of plankton patchiness (8). Much of the
content focused on a statistical analysis of plankton distributions, but Mike was also becoming increasingly interested in the potential of describing plankton dynamics using simultaneous differential equations. In particular, he noted the ideas of John Steele FRS, a mathematical biologist based in Aberdeen, who used variants of the famous predator–prey model of Alfred Lotka and Vito Volterra to investigate plankton dynamics. Mike first met Steele at a North Atlantic Treaty Organization (NATO) Advance Science Institute (ASI) meeting on plankton patchiness in Sicily in November 1977 and subsequently wrote a paper in the follow-up book (edited by Steele), *Spatial pattern in plankton communities* (9). Shortly afterwards, Mike joined SCOR (Scientific Committee on Ocean Research) Working Group (WG) 59, whose remit was to review the state of the art in biological oceanographic modelling and implications for the design of research programmes. Meetings took place in 1977 at the IOS Wormley (renamed from NIO) and in 1979 at the Bellair Research Institute in Barbados. Membership of the WG was limited to a small number of distinguished luminaries including Ken Mann, Trevor Platt (FRS 1998), John Field, Bob Ulanowicz and Fred Wulff. Mike wrote three major sections in the proceedings, *Mathematical models in biological oceanography* (Platt et al. 1981). Mike was now at the very heart of the debate about the choice between holistic methods for studying marine ecosystems versus the reductionist approach based on differential equations. A further meeting of the WG led to the setting up of a NATO ASI in Bombannes, France, in May 1982. Mike had the distinction of being the sole editor of the resulting proceedings, *Flows of energy and materials in marine ecosystems: theory and practice* (11), spanning some 30 articles spread over 733 pages. The stage was set for the move to reductionist methods in marine ecosystem modelling, along with close integration with the field/observational community, and Mike was in pole position to lead the way.

**JGOFS**

Global warming hit the headlines in the 1980s. At the Villach Conference in 1985, leading experts declared that warming is inevitable as a result of a build-up of greenhouse gases in the atmosphere. Climate science entered mainstream politics, discussions over international agreements on CO₂ emissions began and later, in 1988, the Intergovernmental Panel on Climate Change (IPCC) would be established. Research to accurately quantify the sources and sinks of carbon in the global biosphere was imperative and, to address the ocean component, the Joint Global Ocean Flux Study (JGOFS) was launched in 1987. The objectives were to understand, on a global scale, the time-varying fluxes of carbon in the ocean and atmospheric exchange of CO₂, and to develop the capability to predict their response to anthropogenic perturbation. A large proposal was approved for funding by NERC in 1988 as the initial UK contribution to JGOFS and, shortly afterwards, an associated SCOR Committee for JGOFS was set up under the leadership of Bernt Zeitzschel. Mike was delighted to accept an invitation to act as a UK representative, along with Henry (Harry) Elderfield (FRS 2001). The JGOFS field programme got under way in 1989 with the North Atlantic Bloom Experiment (NABE) in which British, American and German ships rendezvoused in the mid-Atlantic to study the spatial and temporal development of the spring phytoplankton bloom (16, 22, 23, 25). This was truly Big Science and, indeed, the JGOFS programme was to last 15 years with participants from more than 30 nations. Mike had the honour of acting as Principal Scientist on *Discovery* 182, the British cruise
contributing to NABE, overseeing an integrated programme of measurements including dissolved inorganic carbon, $pCO_2$, chlorophyll, primary and bacterial production, nutrients and physics. Later that year he was elected as vice chair of the JGOFS Scientific Committee. Mike was now at the very heart of the international effort and his first job was to oversee the writing of the JGOFS Science Plan, which was published in 1990 (15).

Throughout this intense period of activity, Mike was continuing to make remarkable progress in his own personal research. The role of microorganisms in marine ecosystems was becoming recognized at this time, the so-called ‘microbial loop’. Back in March 1984, Mike had attended a symposium on ‘Flow analysis of nutrients in the marine euphotic zone’ held in Quebec and, in the proceedings, he published a flow analysis model of a generic marine ecosystem (that is, not applied to any particular site in the ocean) that included the dissolved organic matter to bacteria to protozoa pathway (12). Results indicated the importance of the microbial loop contribution to total community respiration; for further progress, improved parameterization was needed based on field data for specific ocean ecosystems. In the following October, Mike travelled to San Miniato (Italy) to attend a workshop on photosynthetic picoplankton in the ocean. It was at this meeting that he met Hugh Ducklow, a marine microbiologist based at Horn Point Laboratory (University of Maryland). The two of them struck up a collaboration that, during the years that followed, revolutionized the state of the art of marine ecosystem models. Hugh gave a presentation showing data on bacteria and phytoplankton data from a field study of Warm Core Rings off the northeast US coast (Ducklow 1986). Mike now had the opportunity to parameterize his model accurately, benefiting greatly from both the Warm Core Ring data and Hugh’s expertise in microbial ecology. The two of them attended a SCOR workshop in Santa Cruz in December 1986, ‘Network analysis in marine ecology’ and, in the following year, set about parameterizing the model, with Alain Vezina of the University of Quebec joining them. It was a mighty task given the ‘staggering number of assumptions’, but it nevertheless reached a successful conclusion with publication in the workshop proceedings in 1989 (13).

Flow analysis necessarily assumes steady state, a rather severe restriction given the dynamic nature of most marine ecosystems. Mike therefore again turned his thoughts to the reductionist approach. Steele had paved the way in the 1970s with a simple nutrient–phytoplankton–zooplankton (NPZ) ecosystem situated within the upper (mixed) layer of a two-layer ‘slab’ ocean model (Steele 1974). The idea was developed further by Geoff Evans and John Parslow to make the depth of the upper layer seasonally varying, again incorporating an NPZ ecosystem (Evans & Parslow 1985). Mike and Hugh Ducklow met once more, this time at the joint AGU (American Geophysical Union)/ASLO (American Society of Limnology and Oceanography) meeting in New Orleans in 1988. Mike had set up a time-dependent version of their flow analysis model and could not get it to run successfully. Over coffee and beignets at Café du Monde, the two of them reviewed the parameterizations and found that the rules for the consumption of dissolved organic matter (DOM) needed adjustment to ensure that only the small labile pool was accessed by bacteria. There and then, the model was set in motion once more and it ran successfully! The two of them launched a project that would lead to the famed Fasham–Ducklow–McKelvie (FDM90) model (Scott McKelvie, based at NIO, helped with sensitivity analysis in the latter stages of the work) that would revolutionize the face of marine ecosystem modelling (14). With the slab model of Evans & Parslow as the physical basis, the complexity of the model ecosystem was increased beyond NPZ to include microbial pathways and to divide nutrient between new (nitrate) and regenerated (ammonium) forms. Detritus was
also added as a state variable, facilitating the prediction of export of sinking particles from the surface layer to the deep ocean.

The FDM90 model was set up to simulate Bermuda Hydrostation S, an ocean station in the Sargasso Sea that provided a long time series of data for nutrients, plankton and physical properties of the water column. Mike painstakingly went about formulating and parameterizing the model. Attention to detail was his hallmark and, to keep track, detailed records were kept in notebooks. In all, 201 runs of the model were dutifully listed, exploring his various ideas and parameterizations. Results were sometimes printed out and taped below his jottings (figure 1). The model successfully reproduced the annual cycles of nutrients, phytoplankton, primary production and export for Station S, providing an understanding of the associated cycling of nitrogen and carbon in the ocean. The main legacy of the model is, however, that it provided the basic structure for representing the recycling of nutrients by the marine ecosystem in time-dependent models by including separate state variables for nitrate and ammonium and an associated microbial loop via DOM and bacteria. It thus provided the foundation for the many models that followed; even today, 25 years on, the paper is heavily cited. Of all Mike’s achievements, he is best remembered for the FDM90 model.

For holidays, after so much travelling with work, Mike rejected any destination involving airports and so instead he, Jos and Matthew frequently spent time meandering at 4 m.p.h. along the many tranquil canals of the UK. His penchant for keeping records once again came to the fore as he would note the various species of birds, wild flowers, butterflies and other wildlife, underlining them in Jos’s reference books. His fine eye for detail and thoroughness in approach also served him well with his interests in philately and genealogy. Mike successfully traced his family lineage back to the seventeenth century, at which time the Fashams had been farmers in East Kent. In the 1830s, however, Daniel Stephen Fasham relinquished the farming
Michael John Robert Fasham

tradition and went to sea, becoming a master mariner in Ramsgate, and maybe it was from him that Mike inherited his sea legs.

The International Geosphere–Biosphere Programme (IGBP) had been launched in 1987 to coordinate international research on the effects of climate change on physical, chemical and biological processes that regulate the Earth system. Mike attended the fifth meeting of the IGBP Executive Committee held in Moscow in March 1990, where it was agreed that JGOFS would become a constituent programme of IGBP. As a result of his links with IGBP, Mike later sat on the GLOBEC (Global Ocean Ecosystem Dynamics) Numerical Modelling Working Group and the GAIM (Global Analysis, Interpretation and Modelling) Scientific Committee.

Over and above his committee duties, Mike pressed ahead with his personal research. At the heart of JGOFS lay the development of global models predicting the cycling and export of carbon from the surface to deep ocean, underpinned by intensive sampling in the field. By the late 1980s, computers were beginning to have sufficient power to run three-dimensional models that could simulate the time-varying physical circulation at basin and global scales.

The Princeton group, led by Jorge Sarmiento, was at the forefront of working on these ocean general circulation models (OGCMs). In the earliest simulations, the role of biology in nutrient cycling was parameterized implicitly by restoring nutrients to observed surface distributions by exporting excess nutrient to depth with the use of simple power laws (Najjar et al. 1992).

Mike had met Jorge at the aforementioned ASLO meeting in New Orleans in 1988, initiating a new venture: incorporation of the FDM90 model (while still under development) into the Princeton OGCM. Several visits were made to Princeton, leading to stimulating and exciting discussions among a number of participants including Jorge, Mike, Hugh Ducklow, Robbie Toggweiler, Geoff Evans and Trevor Platt and ultimately publication of the work in 1993 (24). It was the first study of its kind, with an explicit ecosystem model embedded in a multiple (25)-layer general circulation model (GCM) (the ecosystem was restricted to the upper three layers, which spanned 123 m), and run for a North Atlantic domain with seasonal forcing.

Given its pioneering nature and relatively crude model grid, the resulting simulation was a remarkable success, although reported only modestly by the scientists involved, for example the ‘overall pattern of the model predicted annual mean chlorophyll agrees quite well with the CZCS [Coastal Zone Colour Scanner] data’ (24).

In 1991 Colin Summerhayes, then Director of IOS, advised Mike to reduce his commitments to achieve individual merit promotion. Mike enjoyed the committee work but nevertheless reluctantly resigned from the JGOFS Steering Committee, although he remained a member of the JGOFS Global Modelling and Synthesis Task Team (figure 2). Indeed, he attended several North Atlantic Planning Group meetings in the coming years and would take over the chairmanship of the Group in 1995. Mike was also a member of the Numerical Modelling Working Group of International GLOBEC around this time (serving from 1993 to 1997).

Meetings were always a good way of stimulating thought and discussion for Mike and in 1990 a NATO science panel made provision for funding a series of ASI workshops on climate change and the carbon cycle. Mike took the opportunity to attend an ASI on the Global Carbon Cycle held in Cioccio, Tuscany, in September 1991, publishing ‘Modelling the marine biota’ in the proceedings (17). Practical examples were provided, with the usual careful parameterization, by applying the FDM90 model to time series locations in the ocean at Bermuda Station S and Station India (60° N, 20° W) in the North Atlantic. It was another classic publication, a treatise in the state-of-the-art of marine ecosystem modelling. In the following year, Mike visited the delightful Château de Bonas in the Gascogne region of France to attend a workshop that he had
organized along with Geoff Evans of Fisheries and Oceans Canada. The two of them edited the proceedings, *Towards a model of ocean biogeochemical processes* (18), and Mike contributed to three of the papers (19–21). The title of the volume was a long-term aspiration of Mike’s, namely the development of an ecosystem model with a single unique parameter set that could be robustly used in global OGCMs to study the biogeochemical cycling of carbon and nitrogen and their response to changing climate. He set the ball rolling, and the issue remains a topic of debate today. At the very forefront of his field, Mike achieved merit promotion in 1993.

**SOUTHAMPTON**

Alongside his work with Sarmiento in the USA, Mike’s vision was to pursue the development of global ocean biogeochemical GCMs in the UK and two opportunities presented themselves. First, moves were afoot to relocate IOS from Wormley to Southampton. The James Rennell Centre for Ocean Circulation (JRC) was set up in Chilworth in 1990 under the direction of Raymond Pollard, housing physicists and ocean modellers transferred from IOS and an injection of new recruits. Mike was asked whether he would like to transfer to the JRC; the opportunity to be part of a larger group of modellers was too good to miss. Mike and Jos decided not to move closer to Southampton (figure 3) and so Mike started a life of commuting to and from the Rennell Centre. Physical OGCMs were already running at IOS, notably the Fine Resolution Antarctic Model (FRAM) and the development of global models was under way (Coward *et al*. 1994). Second, global simulations using physical OGCMs were also taking place at the UK Meteorological Office. Under its auspices, the Hadley Centre for
Climate Prediction and Research was formed in 1990. What was needed was to incorporate state-of-the-art marine ecosystem models into these physical codes. It was a mighty task and Mike started building his own group of biological modellers. Tom Anderson had already been taken on to work on ecosystem model development, and John Hemmings soon joined the group.

For various reasons beyond Mike’s control, incorporating biology into the IOS physical GCMs was slow to take off the ground and it was with the Hadley Centre that the most rapid progress was made, at least early on. Mike had met with Howard Cattle and Chris Gordon, initiating a collaborative venture in which work was subcontracted to Mike’s group to develop an NPZD model (NPZ plus detritus) and incorporate it into the Hadley OGCM. Expertise was needed to embed the biology in the physical code and to undertake the simulations and Ian Totterdell was taken on for this task. The new ecosystem model was aptly named HadOCC (the Hadley Centre Ocean Carbon Cycle model) (Palmer & Totterdell 2001). Subsequently, this ocean model was embedded within a fully coupled Earth system model that also included an atmosphere and terrestrial vegetation. The resulting HadCM3LC (Hadley Centre climate–carbon cycle model, third configuration) climate model was the first of its kind used for the prediction of the coupled global carbon–climate system (Cox et al. 2000). Mike later contributed to the development of the Diat-HadOCC model (the successor to HadOCC that included the phytoplankton group diatoms), which was used by the Hadley Centre as part of the HadGEM2-ES (Hadley Centre Global Environment Model 2 – Earth System) model for simulations that informed the IPCC 5th Assessment Report.

By now the whole of IOS, including everyone at Wormley, had moved to the purpose-built Southampton Oceanography Centre located at the dockside (now renamed the National
Oceanography Centre, Southampton; NOCS), a union of NERC staff with the oceanography department of the University of Southampton. A supercomputer was installed in-house and with it the development of the global GCM OCCAM (Ocean Circulation and Climate Advanced Modelling). Katya Popova joined the group in 1998 and a new ecosystem model was developed that included phytoplankton, zooplankton, detritus, nitrate, ammonium and chlorophyll as state variables, the latter to assist in model validation. Simulations were performed to study the extent to which global variability in primary production and export production could be realistically predicted using advanced physical parameterizations of the upper mixed layer (42). In recent years global ocean biogeochemical modelling has gone from strength to strength in Southampton, particularly with the development of the MEDUSA (Model of Ecosystem Dynamics, nutrient Utilisation, Sequestration and Acidification) ecosystem model (Yool et al. 2011). It is Mike who must take the credit for providing the foundations of this success.

The global ocean modelling was underpinned by regional modelling studies to provide understanding and insight. As always, Mike’s scientific endeavours continued apace, maximizing opportunity on the back of new and fruitful collaborations. NATO had encouraged Russian scientists to attend the ASIs and it was at Château de Bonas that Mike met Vladimir Ryabchenko and Boris Kagan of the Shirshov Institute in St Petersburg, physicists keen to broaden their horizons into ecosystem modelling. Mike made the first of several visits to St Petersburg in 1994 and at once fell in love with the place describing it as ‘one of my greatest cultural experiences’ (figure 4). Early work focused on investigating the dynamics of the FDM90 model, especially oscillatory and chaotic solutions (27, 30, 31). Further work involved embedding FDM90 into a three-dimensional model of the North Indian Ocean (32, 43) with funding from EC INTAS (International Association for the promotion of cooperation with scientists from the former Soviet Union) and the Royal Society. Tom Anderson took part in this work and also travelled to St Petersburg. The warmth and friendliness of the people were ‘overwhelming’ and could not have been further from the stereotypes of the cold-war era. Departure day was usually celebrated ‘na pososhok’ (one for the road) with a few beers and vodkas. Boarding our flight home one time, Mike and I (T.R.A.) were made to feel decidedly sheepish after a few stern words from a stewardess who was less than happy with our somewhat extrovert disposition! One of the people we met in St Petersburg was Katya Popova, whom Mike was very impressed with. Katya later obtained a Boris Yeltsin scholarship to spend a year working with Mike in 1996 (36). As mentioned above, she has since taken on a job in Southampton working with ocean GCMs and now leads the Ocean Biogeochemical Modelling group at NOCS.

Mike’s experiences with the FDM90 model had taught him that the most time-consuming aspect was varying parameter values to get the best fit to observations. During the Château de Bonas meeting, Geoff Evans had mentioned that he was developing software to tackle this problem by using nonlinear optimization. Another collaboration beckoned in which Mike applied the optimization method to fit ecosystem models to data from JGOFS cruises to the northeast Atlantic in 1989 and 1990 (26, 34). The work embodied Mike’s philosophy that models should be firmly grounded in data to ensure robust and accurate prediction. Indeed, this was the foundation of JGOFS, namely the provision of data via intense sampling (including the time series stations) to understand processes and to parameterize models that could then be incorporated into GCMs to predict the response of the ocean carbon cycle to changing climate. The real world is complex and so, provided that there were underpinning
data, Mike favoured building up complexity in models. Data were obtained not only from the field but also from laboratory studies; Mike was particularly impressed with the work of Kevin Flynn, a physiologist performing laboratory experiments with phytoplankton. He found out that, as a postdoctoral researcher, Kevin had moonlighted as a writer of computer games and so, unlike many biologists, computers and modelling were not alien to him. The two of them subsequently worked on mechanistic models of the interactions of ammonium and nitrate for phytoplankton growth (28, 29), nutrient acquisition and growth of migrating phytoplankton (38) and a mechanistic model of internal cell biochemistry (including iron) of phytoplankton (41). The last of these was applied to modelling field data for the effect of iron addition in the Southern Ocean as part of SOIREE (Southern Ocean Iron Release Experiment).

It was by no means only phytoplankton that interested Mike. During one of the early sessions working with Flynn, he paused from typing in the equations of the NPZ model and, tapping the screen at the ‘Z’ box, remarked ‘this is where the real problem rests, not with the phytoplankton, but with the zooplankton: we need to get this right’. His interest in zooplankton descriptions, meshing also with that of Anderson, led to his revisiting the core structure of his classic FDM90 model to modify the zooplankton equation (44). This, one of Mike’s final publications, bears witness to the character of the man: he was never one for resting on his laurels, nor for sitting back when good science could occupy his mind.

JGOFS was never far from Mike’s heart and in 1997 John Field, who was then chair of the Steering Committee, rang and invited Mike to take over the chairmanship. A new synthesis phase was starting for JGOFS, now that most seagoing activities had concluded. Mike readily accepted, looking forward to at least three years in the job. A new committee structure was
set in place at the following Steering Committee meeting in Cape Town in April 1988, which was successful in stimulating analysis of the vast data sets that had accumulated during the JGOFS years (33). Mike himself wrote synthesis articles summing up the success of JGOFS and providing a vision for the future (35, 37). One of his final achievements was to edit a 297-page book, *Ocean biogeochemistry—the role of the ocean carbon cycle in global change* (39), inspired by the JGOFS programme. He wrote the final summing-up chapter ‘JGOFS: a retrospective view’ (40) in which his concluding sentence was:

One of our challenges over the coming years is to continue the dialogue between modellers and observationalists to ensure that, as computer power increases, ocean models include sufficient complexity to increase our confidence, and that of society, in our predictions of the planet’s future.

Mike himself was a master of that effective dialogue. All who had the pleasure of knowing and working with him will remember his openness and willingness to share ideas, his enthusiasm and positivity, his modesty, wit and, by no means least, lively banter over a pint of beer (especially so if England were winning at rugby!).

**RETIREMENT**

Mike formally retired in 2002, having reached the age of 60 years, although he continued working. He was elected a Fellow of the Royal Society in 2000 and two years later was awarded the Challenger Society Silver Medal. In 2001 he was awarded an honorary professorship in the School of Ocean and Earth Sciences, University of Southampton. Posthumously, Mike was also awarded the ASLO John Martin award in 2010, jointly with Hugh Ducklow and Scott McKelvie, in recognition of their paper of 1990 (14) for its high impact, sustained over many years. Before all of this, in October 1998, Mike was diagnosed with cancer, which came as a huge shock. By early 2000 it had spread and Mike resigned the JGOFS chairmanship, handing over to Hugh Ducklow. Admirably, Mike pressed ahead as best he could with his science, maintaining regular visits to Southampton. He would occasionally arrive at NOC with novel haircuts ‘inspired’ by his bouts of radiotherapy. Mike died on 7 June 2008 and is survived by his wife, Jos, and son, Matthew. He had a stellar career with many publications although, as he himself remarked, quality is more important than quantity, something that is all too often forgotten today. His contribution to JGOFS, both organizational and in terms of his own personal science, was immense. It should also be remembered that Mike continued going to sea throughout his career, doing his bit when it came to the necessary hard graft of seagoing operations. In all, he went on 26 cruises, three as Principal Scientist, the last being *Discovery* 227 to the eastern North Atlantic in 1997. He was an inspirational leader, always down-to-earth and ever willing to collaborate with others in the search for a greater understanding of the marine ecosystem and its role in the global carbon cycle. He is sorely missed by all who knew him.

**ACKNOWLEDGEMENT**

The frontispiece photograph was taken in about 1987 and is reproduced courtesy of Geoff Meadowcroft.
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