SOFI Workshop Report WS 08 02

Modern methods in ecosystem modelling:

Advanced summer school at the

Scottish Association for Marine Science
Oban, Scotland

30 June – 9 July 2008

Sponsored by EUR-OCEANS, Oceans2025 and Quest

Course website:
http://www.sams.ac.uk/research/departments/ecology/summer_school

1. Context – Overview – Organisation credits

The overarching goal of the summer school was to instruct students in the use of various marine ecosystem modelling techniques used for fisheries management, with an overview of which techniques to use with the data available. The summer school focussed on Ecopath with Ecosim; Ecological Network Analysis; Inverse modelling; POLCOMS; C-ICE and the Plankton PZN model. Additional information on these modelling approaches is given in Annex 1.

The strengths and weaknesses of other models were also covered, including minimum realistic models such as MSVPA; individual based models such as OSMOSE; whole, dynamic system models such as ERSEM and ATLANTIS; and other mechanistic and empirical models to deal with spatial ecological problems at small and large scales. A final discussion included a move towards integration of various ecosystem models into end-to-end models that would benefit from the techniques taught at this summer school.

This summer school was organised by Sheila Heymans with the help of Vincent LeFouest and staff at SAMS including Karen Alexander, Shona Magill and Nigel MacLucas. It was funded mainly by Eur-Oceans as part of Workpackages 4 (Ecosystem end to end), 6 (Ecosystem approach to marine resources) and 7 (Within-system integration) and specifically was underwritten by Philippe Cury from Workpackage 6. Additional funding was obtained by two UK initiatives, namely Oceans2025/SOFI and Quest.

2. Goal

This summer school aimed at providing participants with overviews of:

- the theory behind physical and food web models and the methodology used in Ecopath with Ecosim, Ecological Network analysis, Inverse modelling, POLCOMS, C-ICE and PZND models;
- the approaches available for analysing the combined effects of trophic and environmental controls on marine ecosystems, with an emphasis on exploited marine resources.

To reach its objectives, the school relied on lectures, case study presentations, computer lab sessions, and tutorials.

3. Programme

I. ***Introduction***: Various modelling techniques used for an Ecosystem Approach to Marine Resources (EAMR) Duration: 1 half-day session Teachers: Mike Burrows, Sheila Heymans and Vincent LeFouest and Mike Burrows (SAMS)

This section included a broad introduction to various trophic methodologies used for modelling EAMR with special reference to fisheries systems, including MSVPA, Atlantis, ERSEM, OSMOSE. In addition, some alternative ecological modelling techniques used for special ecological issues were described by Mike Burrows including mechanistic models of heat budgets for intertidal animals, linking behaviour to population dynamics, MPA network selection with MARXAN, etc.

II. ***Ecopath with Ecosim and Ecospace***: Describing the theory behind the Ecopath with Ecosim suite of modelling techniques and giving practical hands-on experience with using this approach for EAMR. Duration: 7 half-day sessions Teachers: Villy Christensen (UBC Fisheries Centre) and Sheila Heymans (SAMS)

The Ecopath section of the summer school included lectures and practicals on Ecopath, Ecosim and Ecospace. Villy Christensen gave an overview of EwE version 6, lectured on using ecosystem modelling for fisheries management; and coupling or linking EwE to physical models such as POLCOMS using various techniques possible with version 6 of EwE. The practical sessions were run by Villy Christensen with the help of Sheila Heymans.

III. ***Ecological Network Analysis:*** An overview of the methodologies used in ENA with practical application using NETWRK and EwE. Duration: 2 half-day sessions Teachers: Dan Baird (Stellenbosch Univ, South Africa) and Sheila Heymans (SAMS)

Ecological Network Analysis (ENA) includes input-output analysis, Lindeman trophic analysis, biogeochemical cycle analysis and global system analysis. It is based on matrix algebra and used to describe the total ecosystem flows including direct and indirect flows. As such it describes total system properties not necessarily perceived. The session consisted of an overview and description of the techniques in the morning with a tutorial in the afternoon. ENA in EwE was also described by Sheila Heymans.

IV. *Inverse Modelling:* An overview of the methodology of inverse modelling with a practical example. Duration: 2 half-day sessions Teachers: Nathalie Niquil (Univ of La Rochelle, France)

Inverse modelling is a technique where the uncertainty of inputs to a trophic model iare described and constrained by the biology of the species involved and the parsimony theory. The technique was described using examples from the La Rochelle mudflats studied by Dr. Niquil and her team.

V. *POLCOMS – C-ICE:* An overview of the methodology of and theory behind physical models and the coupling with biological models. Duration: 2 half day sessions Teachers: Miguel Maqueda (POL), Vincent Le Fouest (SAMS)

These sessions covered ocean and sea ice general circulation, the fundamental equations including primitive and tracer equations, sea ice dynamics, sea ice thermodynamics, boundary conditions, numerical models. The practical session covered the methodology of how to run the model in Fortran and how to display the outputs using Ferret.

VI. *PZND models:* An overview of a plankton model and its coupling with physical models. Duration: 2 half-day sessions Teachers: Vincent Le Fouest (SAMS), Miguel Maqueda (POL)

The theory of the tracer conservation equation for ocean transport and the PZND model as well as the coupling of physical and biological models were described and the practical application of these techniques shown in the practical session in the afternoon. Applications of these techniques were shown.

VII. *Discussion:* A discussion of all the techniques described in this summer school as well as how it would be possible to link physical models through PZN to higher trophic level models were held. Duration: 1 half-day session Teachers: Sheila Heymans (SAMS), Vincent Le Fouest (SAMS).

4. List of teachers

There were 6 teachers involved in this summer school, from four different countries (Canada, South Africa, France and the UK), three male and two female:

Prof Daniel Baird , Stellenbosch University , South Africa
Dr Mike Burrows, Deputy-Head: Ecology Dept, SAMS
Dr Villy Christensen, Fisheries Centre, University of British Columbia, , Canada
Dr Sheila Heymans, Lecturer: Ecosystem Modelling, Ecology Dept, SAMS
Dr Vincent LeFouest, Research Fellow: Microbial & Molecular Biology Dept, SAMS
Dr Miguel Maqueda, Research Scientist, Proudman Oceanographic Laboratory, Liverpool.

5. Students

Of 37 applicants, 11 were selected as fully funded attendants to the course. All other applicants were invited to attend at their own costs and 14 additional students did attend on this basis. We funded lunch, the official dinner, buses to and from the venue and from Glasgow for all participants. Participants included 5 MSc and 16 PhD students, 2 students that recently obtained their PhDs, one research fellow and two researchers. The male-female sex ratio was 7:18. Twelve countries were represented in terms of affiliation) and 17 in terms of citizenship (Table 1).

Table 1. Students that attended the summer school *(those in bold paid for by organisers).*

#	Name	Affiliation	Country of affiliation		Euro-ceans	Status	Nationality
1	**Adi Nugraha**	**IUEM, Brest, France**	**French**	**M**	**Yes**	**PhD student**	**Indonesian**
2	Bill Mulligan	Cefas, UK	British	M	Yes	PhD student	British
3	Carrie Byron	Univ of Rhode Island, USA	USA	F	No	Phd Student	USA
4	**Christina Frisk**	**Technical Univ of Denmark**	**Denmark**	**F**	**No**	**PhD student**	**Danish**
5	**Elisa Casella**	**CIMA, Italy**	**Italy**	**F**	**No**	**PhD student**	**Italian**
6	**Erik Gustafsson**	**Univ Gothenburg, Sweden**	**Sweden**	**M**	**Yes**	**PhD student**	**Swedish**
7	**Gwladys Lambert**	**Ocean Sciences, Bangor**	**British**	**F**	**No**	**PhD student**	**French**
8	**Helen Findlay**	**PML, UK**	**British**	**F**	**Yes**	**PhD student**	**British**
9	Heta Rousi	Finnish Env Inst, Finland	Finland	F	No	PhD student	Finnish
10	**Hugo Mendes**	**IPIMAR, Lisbon, Portugal**	**Portugal**	**F**	**No**	**PhD student**	**Portuguese**
11	Kerry Howell	Plymouth University	British	F	No	Researcher	British
12	**Lena Viktorsson**	**Univ Gothenburg Sweden**	**Sweden**	**F**	**Yes**	**PhD student**	**Swedish**
13	Maciej Tomzcak	Technical Univ of Denmark	Denmark	M	No	Phd recent	Polish
14	Marie-Pierre Gosselin	BAS, UK	British	F	No	Phd recent	French
15	Martinez Munoz Marco	CSIS, Barcelona, Spain	Spain	M	No	PhD student	Mexican
16	Morag Ayers	Heriot-Watt University, UK	British	F	No	MSc student	New Zealand
17	Nina Badnarsek	BAS, UK	British	F	No	PhD student	Slovenian
18	Renske Hijbeek	Vrije Universiteit Brussels, Belgium	Belgium	F	No	MSc student	Dutch
19	Selma Pacariz	Univ Gothenburg, Sweden	Sweden	F	Yes	PhD student	Swedish
20	Shona Magill	SAMS	British	F	No	Researcher	British
21	Susa Niiranen	Finnish Inst Mar Res, Finland	Finland	F	Yes	MSc student	Finnish
22	**Tania Mendo**	**Univ of Bremen, Germany**	**Germany**	**F**	**Yes**	**MSc student**	**Peru**
23	Tanya Tsagaraki	Hellenic Centre for Mar Res, Greece	Greece	F	Yes	PhD student	Greece
24	Valentina Lauria	IFREMER, France	French	F	Yes	PhD student	Italian
25	**Vladimir Krivtsov**	**Univy of Edinburgh, UK**	**British**	**M**	**No**	**Research fellow**	**Russia**

6. Summer school 'products'

Training materials

As a summer school by-product, all course materials were compiled on CDs and distributed to every student (the CD includes lecture notes and Powerpoint presentations, exercises and dataset used, students' particulars, and over 200 reprints).

Exercises on datasets/models were performed using the following pieces of software:

- Ecopath with Ecosim version 6, freeware obtainable from www.ecopath.org
- Ecological Network Analysis, using freeware NETWRK, BIGNET and AUTOMOD
- Inverse modelling techniques using Excel ®

- POLCOMS-CICE
- PZN – using FORTRAN

Website

The above mentioned materials can be made available on the course website (lectures and students' projects presentation).

Future networking, including collaborations that might develop between students in NERC Centres and UK universities

Scientists and students from BAS, Cefas, Heriot-Watt University, University of Plymouth, University of Edinburgh and SAMS were able to work together, and future collaborations are highly likely to follow from these interactions. Specific collaborations include Sheila Heymans' work with Kerry Howell from Plymouth University, and Morag Ayers from Harriot-Watt University is doing her Masters project with Sheila. Sheila has also worked with Steve Mackinson and having his student Bill Mulligan (Cefas) here has opened the door for more collaboration there. Enquiries were made to Vincent Le Fouest regarding post-doc and research collaborations from students from BAS and PML.

A Google group was created for all participants to the summer school and will be used for subsequent networking purposes, providing a continued source of information on collaborations, studentships, jobs and dissemination of future events.

7. Funding level and accounts

The contribution of the various sponsors made it possible to cover all travel, food and accommodation expenses of 11 of the 25 students and all teachers. Accounts are reported separately.

Annex 1: Non-technical summary of the importance of the different ecosystem modelling approaches.

Ecopath with Ecosim is a trophodynamic modelling approach that is based on the foraging arena theory of Carl Walters. It has been used by aquatic biologists and for fisheries management and spatial analysis of ecosystem effects in more than 250 publications. Over 30 ecosystems have been fitted to available time series trends. Spatial analysis has been undertaken for at least 5 ecosystems to analyse the ecosystem effects of selected marine protected areas.

Ecological Network Analysis is a suite of algorithms based on the 1st and 2nd law of thermodynamics which states that there is conservation of energy (biomass) and dissipation of energy (flows and heat) in the ecosystem. It characterizes ecosystem level properties that integrates multiple processes and structure and predict indirect effects in ecosystems. It is a holistic approach that has been used to examine the food web dynamics and nutrient dynamics of coastal ecosystems over temporal scales and the impact of fresh water input into estuaries on ecosystem function over spatial scales.

Inverse Modelling is used to estimate missing flows in an ecosystem model where the a priori model of groups in the ecosystem is combined with the equations to calculate flows, biological constraints and the parsimony principle to obtain a unique solution to the flows in the ecosystem. It can be based on isotopic and fatty acid analysis as well as stoichiometry and includes sensitivity analysis as well as a Monte Carlo approach to cover the whole space of possible solutions.

POLCOMS-CICE is a state-of-the-art ocean ocean-sea ice model developed by the Proudman Oceanographic Laboratory. It predicts ocean physical properties like sea ice cover, sea temperature and salinity, currents and turbulence.

NPZD-type models are coupled to ocean models (here POLCOMS-CICE). They have become widely used to infer marine ecosystems functioning. These models are essential tools for oceanographers as ocean "climate" (e.g. underwater light, currents and turbulence) is impacted by climate change and variability. Thus, taking the ocean climate into account in biological models is crucial as it determines the response of the ecosystem. These models are developed with funding from NERC and therefore contribute to the transfer of knowledge from NERC scientists to the greater scientific community.

Annex 2. Course evaluation

Students assessment
Analysis of questionnaire responses (5 pages) provided to SOFI Workshop Coordinator (PW) and available on request

Organiser's assessment *(comments by Sheila Heymans, additional to original report)*

We consider that the course was a success and that most students came away with substantial knowledge about the different methodologies, as on average more than 50% of the students had no prior knowledge of the techniques taught. Most students found the lecturers and practicals very useful and they found (as did we) that it was good to have two people to explain the techniques or concepts at the same time. I found that describing concepts or techniques in different words, formats and graphs than Villy helped some students and broadened the understanding among students. The students have rightly pointed out the technical and software problems experienced in the various techniques, and although we prepared as much as we could for this course there are always unforeseen problems that can only be resolved on site. It was unfortunate that there were many more bugs in Ecopath 6 than in version 5, and that some bugs resolved in v.5 had crept back into v.6.

As one would expect with a summer school with so many different techniques and students with different backgrounds, some students preferred some parts while others preferred others. This would always be the case when such different techniques are combined. It might be more useful to have a shorter more directed summer school based only on one technique (i.e. a week-long workshop on Ecopath with Ecosim, which would have covered the software and its intricacies in more depth), but that would reduce the cross-pollination that we obtained in this school. It was useful for me specifically to learn more about POLCOMS, CICE and PLANKTON and the ideas of end-to-end modelling approaches that came out of the discussion at the end would not have happened if the course was more directed.

Lessons learnt:

1. The organisation of the course was substantial and in future more administrative assistance would be needed.
2. Give the students a full weekend, not just one day off, as they (and we) were overtaxed. The reason we did that was to save costs, and possibly having students pay for the course instead of trying to fund it all would alleviate that.
3. Paying for some students and not for others caused some problems, but we thought it would be better to invite those that did not make the cut for the funding to attend at their own expense. However, it still caused discontent.
4. Although one would want to give students the newest and "best" versions of software, it might be more prudent to use more tested versions.
5. Test the hardware extensively.