TAKING A BROADER VIEW OF ECOSYSTEM MODELLING

WGIPEM and the creation of responsive virtual worlds.

During the past twenty years, the coupling of biological and physical models has improved our understanding of the dynamics of marine species and the ecosystems in which they live. Some models, particularly three-dimensional, biophysical, individual-based models (IBMs) and multispecies population models, have been part of the ICES portfolio for a long time, particularly through the ICES Working Group on Modelling of Physical/Biological Interactions (WGPBI).

Parallel with the development of IBMs and multispecies/upper trophic level models, has been the development, under the generic term "end-to-end" models, of a number of spatially explicit foodweb models, with diverse frameworks and emphases. Initially, this new generation of integrated modelling attracted the interest of the academic scientific community, but recently it has attracted marine resource managers and applied scientists. These coupled models are appealing because they integrate various parts of the ecosystem and can incorporate human and environmental drivers in a single framework.

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ICES Science Committee (SCICOM) identified this area, which has developed largely outside the traditional ICES community, as a gap in its science portfolio. Working with members of the modelling network and academia, SCICOM dissolved WGPBI in 2011 and created ICES Working Group on Integrative, Physical-biological, and Ecosystem Modelling (WGIPEM), which is meant to take a broader view of ecosystem modelling.

"It's time to take it to the next level, which is end-to-end modelling", says Myron Peck, Co-Chair (with Miguel Bernal) of WGIPEM. This means coupling individual models produced by groups such as WGPBI and inserting the human element at the top, thus creating virtual worlds that can help us understand how ecosystems respond to changes.

For Peck, trying to combine models and identify their utility for answering questions about fish stocks and assessment requires a common language. Creating such an environment of mutual understanding, where many different aspects of modelling can be discussed, will be one of the group's main tests.

Communicating with other ICES working groups will be a priority. "Our task is to make sure that the other groups understand what our models can and can't do." As an example of fruitful intergroup cooperation, Peck cites the ICES Working Group on Operational Oceanographic Products for Fisheries and Environment (WGOOFE), which established a web portal that acts as a two-way link between the producers and the users of oceanographic data products (www.wgoofe.org), and its close association with the Herring Assessment Working Group for the Area South of 62°N (HAWG), which contributes heavily to the site.

The first meeting of WGIPEM covered a wide field of topics, presenting cutting-edge science and innovative ecosystem modelling tools. The meeting, held in March 2012, attracted fifty participants including global experts in the field of modelling.

Peck feels that the meeting went well: "The group mixes people having lots of ICES experience with people who have never previously worked together. When we met in smaller discussion groups, people started to see the things they have in common and realize how they could work together to advance the field. We identified at least four specific topics that will improve end-to-end models, as well as many other kinds of models."

The challenge will be to keep the far-flung group meeting regularly. "We have to make sure that they can continue to meet, because each member offers expertise that is quite rare".

Peck envisions cooperation with other international groups in the future. "This is not just an ICES issue, but is very important for effective spatial planning and management of marine ecosystems throughout the world."

"The scientist is not a person who gives the right answers; he's one who asks the right questions." – Claude Lévi-Strauss

Some of the international experts attending WGIPEM's first meeting in Copenhagen took a moment to discuss the development of marine ecosystem modelling.

Enrique Curchitser is an oceanographer based at Rutgers University in New Jersey, USA. His main interests are the intersection of climate and ecosystems, regional climate impacts, and numerical modelling.

Beth Fulton leads a marine ecosystem modelling team based at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Marine and Atmospheric Research in Hobart, Australia. She led the development of Atlantis, one of the world's most successful models in the field of whole-of-ecosystem modelling for the marine environment.

Kenneth Rose is a professor at Louisiana State University Department of Oceanography and Coastal Sciences in Baton Rouge, Louisiana, USA, working on computer simulations of fish population dynamics, with particular interest in modelling fish movement in space.

Olivier Thébaud is a resource economist at CSIRO, Brisbane, Australia, working on how to bring the human dimensions into models in terms of how people interact with the ecosystem, but also in terms of economic impacts and social dimensions.

"Using humans as a computational part is powerful, because humans can make intuitive leaps that computers cannot."

Q: Let's start at the beginning: How do you build a model?

Beth Fulton:
There are two parts in making a model. On the one side, there is the software that you use, and on the other side, there is the actual model building. Therefore, the way that we approach building a model is to sit at the drawing table and ask, "What are the key parts that we need in the system?" Then you go to the software to tie the right bits together to build a computerized version of what you have drawn on the whiteboard. These two slightly different sides come together in your end result.

Kenneth Rose:
Another way to think of it is in terms of a model and a code. The model is the mathematics which represent the key parts in the system, and the code is how you solve those equations.

Q: The model builders must therefore input the equations; they are not created by the computer?

Kenneth Rose:
Exactly. Computers are fast, but not smart. They are amazing if you repeatedly tell them what to do, but you do have to tell them what to do. In terms of model building, this means the equations that you come up with.

Q: How objective or subjective are models builders in deciding what should be included?

Olivier Thébaud:
It is not so much a question of who decides what should be in a model, but rather what the question is that people want to address with a model, which will lead then to the choices made. For example, if we want to be able to predict what might happen in the uses of the ocean, then that is the question which drives what you include and what you factor out in a model.

Several models of the same system can exist and each of these will have a different way of representing things. This is because there are different questions that people want to address through the models. One of the challenges of the whole end-to-end debate is whether we need to bring some of these different models together to get a more integrated vision of what is going on, and if so, how?

Enrique Curchitser:
I agree with Olivier. I think fundamentally we write models to make projections and predictions; the reason to create a model is to make a projection of some future state. The framework that decides the complexity of a model and therefore what is included will be dependent on the questions asked and the time-scales.

Beth Fulton:
I would like to add that some of the questions come from the public and politicians, who are now demanding more complex ecosystem information rather than single-stock or single-species information.

Q: Do you try to be right when you make models? And, if so, how do you know when the model is right?

Beth Fulton:
It is not about being right; it is about helping people think about the system in a new way, which will give them an insight into decision-making. The way we naturally think is very linear, so models help people understand more complex systems with feedbacks and interactions. Models help people see that, if they change one factor in the system, this can also cause changes in other factors.

Q: Are you saying that models can be used to teach the public, or non-scientists, a different way of thinking, a different way of anticipating?

Beth Fulton:
Certainly. In Australia, we have created simpler, user-friendly versions of the models, which can be played on iPhones or small laptops. So, it is not only stakeholders, but also the general public who are able use the models. This means that everybody learns together.

Olivier Thébaud:
In fact, it is often a two-way process. The interaction with stakeholders and the public provides us, the developers, with information and understanding which were not captured in the models initially. This is useful, particularly when you are trying to capture some of the human dimensions within the models.

Beth Fulton:
Yes, we learn by watching people play; we give them the model, they play, and we observe that, "Well, they made their decisions this way," or, "We never thought about that facet of interaction with each other when making their decision."

Q: Can models be developed into computer games and virtual worlds?

Olivier Thébaud:
Yes, it is a growing field; they call it companion modelling. There is a whole network internationally that is developing models alongside these interactions with the stakeholders. Experimental context and workshop settings are used to enable people to play a virtual game where they can learn about other people's views. For example, you get different water quality managers to play a model-based video game, where, essentially, people can select various options. You then get the participants to change their roles to see what the other person across the table has in terms of decisions to make.

Beth Fulton:
Using humans as part of the a part is powerful, because humans can make intuitive leaps that computers can't.

Olivier Thébaud:
But there are still a lot of questions as to how you bring that information back into the whole model development; so this is still a developing area.

Q: Is it possible to take "the unexpected" into account in models?

Beth Fulton:
There are a couple of ways to approach this. In one way, you just have to accept that it is not possible to anticipate everything. But you can also try to shock the system to see what would happen; what you don't say is, "This event will happen", instead you ask, "What if it happened? How would we respond?"

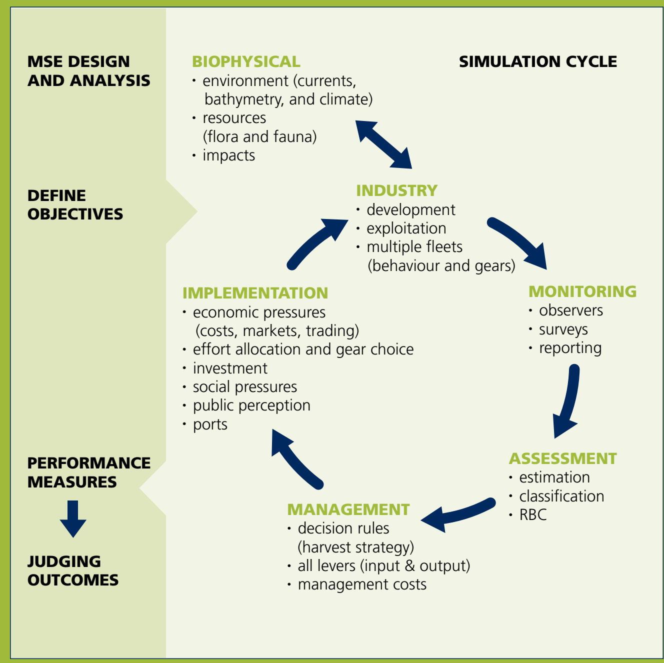
Q: How do end-to-end models relate to the more traditional methods in marine research?

Beth Fulton:
I can answer that from the Australian perspective. We are not in competition with the stock assessments in Australia, we work in parallel. Stock assessments are still used to make the day-to-day, year-to-year decisions, whereas ecosystem models are used to give strategic context for those decisions. They don't compete, but rather complement each other.

Interview conducted by William A. Anthony.

Atlantis

The Atlantis model is considered the foremost ecosystem model worldwide. Developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia, it is a model that considers the ecosystem in its entirety (Fulton *et al.*, 2004). Physical, chemical, ecological, and fisheries dynamics information are integrated in a spatially-explicit, three-dimensional domain. The overall structure of Atlantis is based around the Management Strategy Evaluation (MSE) approach, where there is a sub-model (or module) for each of the major steps in the adaptive management cycle. When first developed, the model's focus was on the biophysical world and gradually progressed to address fishery management questions (the first in the world to do so) which has become its primary use. However, Atlantis has now evolved to the point that it is being used to explore multiple uses of marine systems and climate questions. There are more than nineteen Atlantis models in use today, mainly in Australia and North America. The first ICES region to introduce an Atlantis model is the Barents Sea (run by the IMR). The first case study from this model which observed the effect that migrating whales have on the Barents Sea ecosystem will be discussed during ICES Annual Science Conference 2012. New Atlantis models are being parameterized for the North Sea and the Channel that will include interactions among various economic sectors and activities such as fisheries, renewable energy, shipping and conservation. These new models were discussed at the first meeting of the ICES WGIPEM.



▲ *Atlantis model structure – based on the management strategy evaluation cycle. Courtesy of CSIRO.*

Literature cited

Fulton, E. A., Smith, A. D. M. and Johnson, C. R. 2004. Effects of spatial resolution on the performance and interpretation of marine ecosystem models. Ecological Modelling 176: 27–42.

▼ *Systems where Atlantis is in use or under development (red) or proposed (blue). Courtesy of CSIRO.*