Towards a predictive model supporting coral reef management of Bonaire's coral reef. Progress report 2012.

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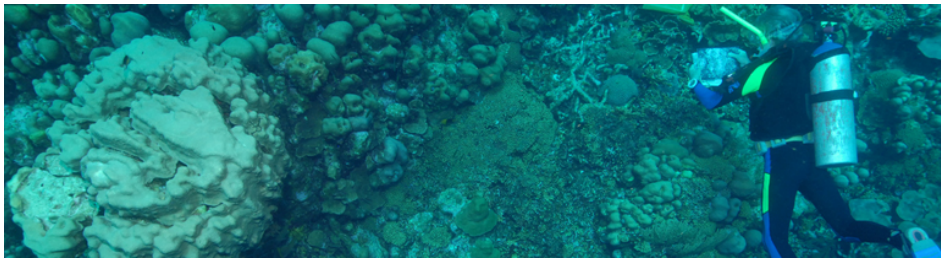

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1 Introduction

As part of the policy supporting research (“Beleidsondersteunend Onderzoek”) of Wageningen University, IMARES has been asked to give a view on the possibility to develop a working model for the coral reefs of Bonaire that can be used to predict consequences of management actions. The assignment by the Ministry of Ministry of Economic Affairs (EZ) included a workshop (held on 26 November 2012) with Dutch specialists in the field of ecosystem modelling from IMARES and Royal NIOZ to determine how to develop an ecosystem model that can be used to assess the main impacts on the coral reefs of Bonaire and that will provide a tool to help evaluate the consequences of human actions. This model would need to assist nature management and policy in the area of anthropogenic impacts, one of which is the invasive lionfish.

This report outlines the main results and conclusions of the discussions held.

2 Workshop participants

Participants in this workshop were:

Bert Brinkman (IMARES)
Brinkman is the developer of ECOWASP an ecosystem model of the Wadden Sea that is being used in numerous studies on the dynamics of birds and benthic animals in the Wadden Sea.

Piet Ruardij (NIOZ)
Ruardij is the main developer of ERSEM an ecosystem model of the North Sea. ERSEM is one of the most extensive models available. ERSEM was originally developed, refined and applied in two EU Marine Science and Technology (MAST) projects by shifting consortia of leading marine science institutes in Europe, from 1990 to 1996. For more information see http://www.nioz.nl/northsea_model.

Fleur van Duyl (NIOZ)
Van Duyl is a coral reef ecologist with a long-term knowledge of the reefs of Bonaire and Curaçao. She started in the early eighties with the production of the reef atlas for both islands and continued with research into nutrients, dissolved organic matter and bio-erosion processes on coral reefs.

Alma de Groot (IMARES)
De Groot is working on the interface of ecology and physical geography in salt marshes and dunes. She has recently developed a model for the formation of coastal dunes and their associated vegetation development, with which the impacts of various environmental factors can be simulated.

Daan Gerla (IMARES)
Gerla works as a postdoc scientist at IMARES and NIOZ and works at improving ERSEM.

Pepijn de Vries (IMARES)
De Vries works on ecological risk assessment, originally from an (eco)toxicological perspective. He has also worked on integrating both toxic and non-toxic stressors, resulting from a wide variety of human activities. In a case study of the Wadden Sea the impacts of human activities are estimated using the RAM principles as developed in the nineties (http://edepot.wur.nl/201100).

Jaap van der Meer (NIOZ)
Van der Meer is a theoretical biologists working on Dynamic Energy Budget (DEB) models of a variety marine organisms (bivalves, gastropods, crustaceans, fish) and applying models at the individual level as building blocks in individual-based population models.

Erik Meesters (IMARES)
Meesters has studied the reefs of Curaçao and other places in the world since 1988. For his PhD degree he studied the ecological role of damage and regeneration of corals. He is now coordinating the policy related research in the Caribbean Netherlands for the Ministry of Economic Affairs.

3 Workshop results

In preparation of the workshop, all participants received two papers. One by Polivina (Polovina 1984) which describes a coral reef model based on the fisheries model ECOPATH. The other paper describes a well-known coral reef model which has been used a lot recently and was developed by Mumby and co-workers in the last 10 years (Mumby et al. 2007, Edwards et al. 2010). Meesters presented a talk on the coral reefs of Bonaire, coral ecology and the general threats to corals. After this the participants were asked for their first impressions. A summary of these first comments is given below.

What is missing in the models presented in the papers, is the interaction with the ocean currents and primary production. Possibly, nutrients from other areas have an effect on the sea around Bonaire. Van Duyl remarks that this is quite possible in certain periods of the year when there is upwelling north of Venezuela and when outflow of the Orinoco influences the water quality, both influences can reach Bonaire and Curaçao.

An individual-based model could be used to model the basic entity of a coral reef, namely the host-symbiont (coral-zooxanthellae) unit. One would have to start from that and build a Dynamic Energy Budget (DEB) model and extend that to larger areas including many different colonies in an individual-based approach.

The questions are very broad and still rather vague. The effects of human activities that the model should address should be much better described and limited. What accuracy is necessary? What cause and effect relationships are known? Will effects be cumulative or will each activity only be related to one effect? The answers to these questions will have a lot of influence on the kind of model that needs to be developed.

Questions need to be much clearer. What information is available from the Great Barrier Reef? Often coral reef management involves Marine Protected Areas (MPA's), including marine reserves in which fishing is banned. The current consensus seems to be that such MPAs should be part of protected-area networks (Gaines et al. 2010). In the Caribbean, such networks would include areas of different countries. MPA network design may benefit from hydrodynamic models for the dispersion of organisms (Munday et al. 2009). For instance, empirical evidence suggests that coral reefs adapt to higher seawater temperatures through natural selection, gradually reducing susceptibility to bleaching (Rowan 2004, Sampayo et al. 2008, Thompson & van Woesik 2009) and that genetic connectivity between reefs contributes to the capacity to adapt (Underwood et al. 2007). Also, fish recruitment may be partly determined by coral reef connectivity (Armsworth 2002).

There is a need to model the production of the whole ecosystem, including the circulation of nutrients, dispersion (import and export), consumption of primary production by fish, overproduction, bottom-up preferably, and to include the effects of acidification.

The model needs to be spatial and dynamic. Possibly we can start with available models? Should the model include the effects of the sewage treatment plant? Likely there is a link with terrestrial ecosystem modelling, like for savanna's where herbivores also play a structuring role. Modelling the interactions between different trophic levels is also crucial.

There is an already existing model called ReefMod by P. Mumby. However, in that model, primary production, microbes and microbialization and pelagic benthic coupling appear to be missing. The role of micro-organisms is totally missing in the processes as are sponges. Recent research has shown that

sponges provide important services to the reef. Human disturbances influence these microbial processes which in turn affect ecological processes on the reef.

After this first round of comments, the discussion was continued. It was concluded that, depending on the question, different models may have to be developed. A fisheries model will not be able to answer questions on benthic communities. Ecopath appears not to be usable to incorporate the effects of human actions other than fish extraction. Furthermore, it is not dynamic, but mostly static (even with the extension ECOSIM).

It was felt that target questions should become clearer. If it is clear what questions need to be answered it may be possible to evaluate if an existing model may be able to address these effectively. For example, nutrients may have a strong effect on the competition between algae and corals.

Bathymetry will be necessary if hydrodynamics have to be included into the model. This could be done by Janine Nauw of NIOZ whereby a new model needs to be derived by downscaling from a larger existing model (e.g. from Claire Paris from RSMAS in the US). For exchange of nutrients from the pelagic phase to the benthic phase, a hydrodynamic model will be necessary. This is also the latest stage in the North Sea model where scientists are now working on the coupling between a hydrodynamic 3D model and the benthic community (see also http://www.nioz.nl/northsea_model).

The discussion then focused on whether it would be better to develop a new model or to try to use an existing model. Opinions differed mainly between the more fundamentally-oriented modellers who favoured the development of a new model based on past experiences including DEB modelling and hydrodynamic modelling, and the scientists with a more applied approach who appeared to be more in favour of the use of the model of Mumby et al (2007), or to create simpler and smaller models. A hydrodynamic model would be possible to develop in a relatively short period of time, while simultaneously a first DEB model could be built for the coral host-symbiont animal. For a fully functional new model however, a multiannual? project, for example a PhD project, would probably be necessary.

4 Future

It is suggested to develop a two-way track, one, focused on short-term results and another focused on a longer term path. On the shorter term, adapt REEFMOD (Mumby et al. 2007) to the Bonaire situation (and questions) to have a first model available for first-order indications. One back-draw is that this model cannot easily be coupled to a hydrodynamic model. Also REEFMOD is as yet only simulating the reef plateau and not the reef slope, which forms a substantial part of the reef on Bonaire.

On the longer term, developing a preliminary DEB model or other mechanistic model and simultaneously creating (and coupling) a regional hydrodynamic model using all the available knowledge at NIOZ and IMARES, could probably produce a very good model. A new model should contain the most import functional groups. The most important functional groups of benthic organisms are the primary producers (calcifying and non-calcifying), the suspension/DOM feeders (bioeroding and non-eroding organisms), the deposit feeders, and the crawling grazers (like urchins). Crucial pelagic groups are the grazers, the benthic invertebrate feeders, and the predators. Biomass and production of plankton (phyto-, bacterio-, and viroplankton) form important externally-derived nutrition. Furthermore, there is endogenous nutrition produced by local benthic production. This would enable the simulation of accumulation and turnover of organic material on reefs, based on the contributions from and fluxes between the different functional groups.

At this moment a student working with Jaap van der Meer is developing a DEB model for the coral-symbiont unit. Additionally, we are planning to write an NWO proposal for a PhD student to develop a mechanistic model starting with a benthic production model and transforming it into a fully functional ecosystem model.

To develop the hydrodynamic model, one would first have to make an inventory of available larger-scale models and investigate the relative contribution of nutrients from South America (related to changes in land-use in this region) in comparison to the contribution of nutrients from Bonaire (and other islands close by). If there is sufficient evidence that these dynamics at larger scales contribute significantly to the reef processes of Bonaire, such a hydrodynamic model will need to be developed. It can be developed from already existing models. A good 3D bathymetric model of the reef is crucial for hydrodynamic modelling. It can be proposed to the Hydrographic Service for their next survey round (probably 2016) in the Caribbean Netherlands. Also, there may already be data available from researchers in the U.S.A.

Contact with Mumby has resulted in a positive reaction, and willingness to share his model and provide us with the necessary input to start using and adapting this model to answer the relevant questions. The adaptation of the model to the Bonaire situation, and to answer relevant questions, will also need extra investments. To answer questions related to the lionfish, most scientists thought that a completely different model would be necessary. However, depending on the question, it may be possible to include lionfish effects on the coral reef if the effects of the lionfish in the system are principally through its impact on resident herbivorous fish populations. This however, would require additional data on the mechanisms by which lionfish affect the reef ecosystem.

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Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

Justification

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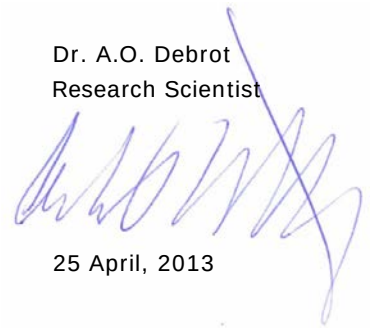
Project Number: 430.82010.87

The scientific quality of this report has been peer reviewed by a colleague scientist and the head of the department of IMARES.

Approved: Dr. A.O. Debrot
Research Scientist

Signature:



Date: 25 April, 2013

Approved: J. Asjes, MSc.
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Date: 2 May, 2013