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Abstract

This document presents the advanced models developed in correspondence with the topics defined in DynaLearn's Environmental Science curriculum (D6.1). The topics covered for the different themes comprising: Earth systems and resources: ciliate factors; the living world: Habitat dynamics; Pollution: The chemistry and physics of marine environments; Human population: Biotechnological exploitation of marine organisms; and Energy, resources and consumption: Primary production. The models were developed in Learning Spaces 4 and 6 (LS4, LS6) of the DynaLearn prototype workbench.

Internal Review

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Document History

Version	Modification(s)	Date	Author(s)
01	First draft	2011-09-10	Leiba, Zurel, Mioduser, Benayahu
02	Second draft	2011-09-15	Leiba, Zurel, Mioduser, Benayahu
03	Deliverable for review	2011-09-30	Leiba, Zurel, Mioduser, Benayahu
04	Final deliverable	2011-10-10	Leiba, Zurel, Mioduser, Benayahu

Contents

1. Introduction

The aim of task 6.4 of the DynaLearn project was to develop more advanced content and models for the repository and the curriculum in Environmental Science. This deliverable presents the second set of models (task 6.4) developed at Tel Aviv University in correspondence with the curricular topics defined in the deliverable D6.1 and discussed in deliverable D6.3.

TAU's models pertain to 5 different topics associated with 5 main themes (out of 7) defined as major themes for DynaLearn's curriculum in Environmental Science. The topics were selected according to their relevance for the Israeli Environmental Science curricula; their adequacy to the local context environmental characteristics, hence their relevance to the definition of authentic context-based educational objectives; and their potential for promoting learning enhancement using the tools provided in the DynaLearn workbench at the different Learning Spaces.

1.1 What are advanced models?

Deliverable 6.3 (Noble et al., 2011) discussed the concept of "advanced models" and its implications, and concluded that advanced models should fulfil the requirement of being independent units of system oriented knowledge that could be re-used in different curricula on environmental science. Furthermore, the advanced models should be insightful and situated at an appropriate level of complexity to capture insightful explanations of phenomena, taking best advantage of the available features of each Learning Space in DynaLearn.

The features identified for “advanced models” include:

1. More complex models, that provide insightful explanation for more complex domain phenomena.
2. Representing more complex phenomena equals integration of basic laws and first principles to address a more complex problem.
3. Including more elements on the model, refining concepts (requires complex LS 2-4 models, and LS5 and LS6 models.
4. Describe mechanisms that explain how things work and integrate.
5. Develop formal explanations for the system behaviour of advanced topics.
6. Advanced models should better explore the software capabilities.

D6.3 argued that models have to be developed following clear goals and should consider content knowledge, generic system patterns and the available features of each Learning Space of DynaLearn simultaneously. Furthermore, advanced models need to have the appropriate level of complexity to gain the maximum learning effect in terms of their ability to explain phenomena. Therefore, advanced models, in the context of refined DynaLearn curricula, are not just models that cover more complicated concepts but can also be seen as a refinement of models, using the best modelling practice identified (e.g. make best use of the qualitative systems approach for conveying conceptual knowledge). The models delivered as part of D6.4 should therefore:

1. Be clearly and suitable framed within a domain topic and an appropriate curricula context.
2. Make appropriate use of different Learning Spaces to convey explanations for conceptual ideas.

3. Be optimised for their use by the technological components of DynaLearn (in conjunction with using advanced modelling ideas to define how the technology should function).
4. Have consistency in their design and the approach to nomenclature from an expert, technological and educational perspective.
5. Act as a resource base of knowledge for the DynaLearn curriculum in the repository to support evaluation activities of feedback technologies.
6. Showcase the opportunities and technologies created by the DynaLearn environment

In accordance with D6.1 (Salles et al., 2009) DynaLearn project framed the topics and content developed to achieve content-specific goals within suitable generic learning goals. Following our modelling experience, we believe that the modelling process, in the case of a pedagogically-oriented tool as DynaLearn, is characterized by the need to integrate three sets of considerations: Subject-matter and disciplinary considerations (scientific contents and definitions), the modelling approach and language (in this case QR and the tools offered by DynaLearn) and pedagogical considerations (e.g., the expected educational value of models in the different learning spaces, of different levels of complexity, or different levels of coverage of the modelled phenomena). As such, we see another aspect to what are "advanced models" – the thinking skills required from the students who model these phenomena.

The learner oriented (what is required from the student) skills that we envision in advanced modeling are:

- Decision making
- System thinking
- Scientific reasoning
- Argumentation

2. Topics and models

2.1. Context for the models developed

The current curricula on Environmental Science in Israel foster the development of interdisciplinary skills, environmental skills, social and reflexive skills, economic skills, technical skills, jurisprudential skills and language skills. Developing such skills and knowledge (e.g. the identification of interconnections; integration of different paradigms and points of view; feeling responsible for the environment; global thinking and local acting; identification of the conflicts of environment; economy, society and science; identification of the landscape as habitat; sustainable management and sustainable use of resources; and environmentally friendly economy) are the focus of our implementation of DynaLearn in the curricula.

Science and technology constitute key factors in achieving sustainable economic development throughout the Mediterranean (MED) and Red Sea (RED) regions. Both MED and RED are considered as European Seas. They are environmentally unique, but unfortunately suffer from severe anthropogenic impacts and environmental threats. There is thus a need to seek and develop practical tools aimed at reducing the use of raw materials, water resources, land and energy, and the generation of waste materials, as well as conservation and preservation concepts of the coastal resources of both seas. A well-established objective of the EU countries is to establish a platform which will address key needs of sustainable development in the marine environment, in general and in particular in the semi-closed MED and RED seas, which are highly vulnerable to anthropogenic impact. These objectives are strongly linked and amalgamated with the recognition of the need to develop educational tools in order to increase the awareness of the pressing environmental issues, including global change, and provide practical protocols for both dissemination of the subject and potential solutions.

The marine environmental issues in Israel are being addressed by developing viable solutions to the fundamental environmental problems confronted by the countries in the Mediterranean Basin and beyond (see EuroMed project, GEF project in the references list). In Tel Aviv University, environmental issues are being addressed primarily at The Porter School of Environmental Studies (PSES). The PSES promotes novel areas of interdisciplinary environmental research and places environmental issues on the academic and public agenda. These interdisciplinary issues include areas such as environmental friendly technology and climate change, biodiversity, global warming and renewable energy, epidemiology and sustainability.

The marine environment plays a vital role in our country, as it provides cultural, biological and physical resources, as has also been shown throughout the history. The focal geographic location of Israel at the crossroads between the East and EU (West) further emphasizes that importance of the marine environment there and the need for comprehensive efforts to integrate the subject matter in any curricular/ educational agenda. The marine biology curriculum at TAU includes a variety of courses at the undergraduate and graduate levels, as well as outreach activities among youngsters (elementary, junior high and high schools, gifted and low socioeconomic levels and minorities). The activities expose the students to coral reef, sandy and rocky shores, sea grass beds, benthic and pelagic zones, estuaries and man-made habitats. Besides that, the local context shows the strong relevance of understanding environmental problems related to climate change, invasive biology, desertification, water resources shortage, agriculture and soil exploitation, and sustainable development.

TAU's models are associated with several coastal ecosystems that are found in Israel, relevant to EU seas. These include coastal sand-stone cliffs, sand dunes and artificial habitats (jetties, marinas, etc.) coral reefs and intertidal zones, sea grass beds, benthos and pelagic zones. Additionally, several ecological processes will be addressed in each ecosystem (and model). For example process such as ecological succession, invasive species and migration, population ecology, prey-predator interactions, food chain and competitive interactions will be addressed. Understanding the processes affecting these ecosystems will allow the students to comprehend their importance and will also assist them in planning conservation strategies for them.

The environmental science topics delivered by TAU aim at the development of an understanding of several issues: the natural processes and the effects of human activities on the environment; "human-nature" and "nature-economics" relationships such as tourism and its effects on the environment; and the effects of global change on living conditions and the environment. The basis for understanding the effects of human behaviour on the environment is formed by learning about natural environmental and ecological factors and processes acting on local and global scales. (For additional relevant background see: e.g., Airoldi, Balata and Beck, 2008; Bouduresque and Verlaque, 2002; Por, 2009; Rilov and Crooks, 2009).

2.2 Links to DynaLearn Curricula (D6.1, D6.3)

The selected topics are presented in accordance to their relevance to environmental science curricula focusing on exploring marine systems, together with their relevance to the general DynaLearn curriculum based on the 7 themes (Salles et al., 2009):

Earth systems and resources

Habitat dynamics - To identify processes relevant for the creation and maintenance of habitat features, necessary to assure the survival of a specific or community; To model how natural processes influence the structure and quality of habitats required for a specific population or community as a basis to develop sustainable management strategies. (See section 3.5: ocean warming and the nutrient cycle).

The living world

Community specific features- to model specific features of biological communities, as species diversity, disturbance and resilience, complexity and succession; to compare specific features of different biological communities (See section 3.6: carbon capture and toxic blooms).

Human population

Biotechnological exploitation of marine organisms - to establish causal relations among relevant elements from society, culture, economy and environment related to the exploitation of marine organisms in biotechnological perspectives and applications; to demonstrate that protection of biodiversity may improve the conditions of a particular society in a given situation described in a case study (See section 3.1: control of Zebra mussels using bacteria).

Pollution

The chemistry and physics of marine environments - to identify relevant chemical and physical aspects of marine environment and establish causal relations that may explain changes in structure and behaviour of these systems due to pollution; to compare possible solutions to the effects of pollution events on the basis of social, cultural, economic and environmental aspects in specific case studies (See section 3.2: oil spill affecting a marine ecosystem).

Energy resources and consumption

Primary production - To identify the most relevant factors involved in the production of biomass by the photosynthetic process and establish causal relations involving environmental factors with primary productivity; To represent how human actions and natural events may hamper or improve primary production and what are the consequences for natural systems and for social, cultural and economic aspects of human systems (See sections 3.3 and 3.4: coral reef global distribution; and nutrient upwelling).

The following table summarizes the topics and models developed at TAU.

Table 2.2.1 Summary of themes and topics from the D6.1 curricula in Environmental Sciences and the models covered in TAU D6.4.4.

Theme	Topic	Sub-topic	LS04	LS05	LS06
Earth Systems and Resources	Climate factors	Warming and the nutrient cycle			✓
Energy resources and consumption	Primary production	Coral reef global distribution			✓
	Primary production	Nutrient upwelling	✓		
The Living World	Habitat dynamics	Carbon capture and toxic blooms			✓
Pollution	The chemistry and physics of marine environments	Oil spill affecting a marine ecosystem			✓
Human Population	Biotechnological exploitation of marine organisms	Control of Zebra mussels using bacteria			✓

The models in this deliverable were developed using Learning Space 4 and 6 (LS4, LS6). LS4 allows constructing a causal differentiation model. The modeller can differentiate between processes and quantities that propagate causality (Influences vs. Proportionalities). This enables models to be developed with qualitative causal relationships .In addition, LS6 allows constructing a model using a generic and reusable knowledge (model fragments). LS6 enables the modeller to use the knowledge in the model in separate model fragments. Different scenarios describe different initial situations of the system and enable to run different simulations. LS6 is the most complete model a modeller can construct, beginning with the definition of entities and quantities, defining causal relationships, reusing knowledge and interpreting the simulations.

3. Advanced Models

3.1 Biological control of Zebra mussels using bacteria

Theme / Topic	Population - Biotechnological exploitation of marine organisms		
Author	Dror Zurel and Moshe Leiba	**Version(s)**	DL v0.8.5
Model	Zebra mussel - LS6		
Target users	Undergraduate students, high school students		

3.1.1. Background

Power plants have been faced with a major problem — zebra mussels, invasive strains of very small mollusks, have been clogging power plant water intakes. Power generation facilities require annual maintenance to keep the proliferation of zebra mussel (see Figure 3.1.1) infestations in their cooling water intake systems under control (see Figure 3.1.2). Currently controlled dosages of chlorine or other types of chemicals are used for this purpose. However, these chemicals cause long-term damage to the aquatic ecosystem. Additionally, Zebra mussels appear to adapt to chlorination, rendering it useless for their eradication (Molloy, 2002).

Figure 3.1.1. Zebra Mussel (*Dreissena polymorpha*) (retrieved from http://www.netl.doe.gov)

Figure 3.1.2. The small zebra mussels densely colonize inside cooling water intake pipes of power plants, thus leading to significant power outages and expense (retrieved from http://www.netl.doe.gov)

It was hypothesized (Molloy, 1991) that bacteria also existed in nature whose toxins could be used as lethal agents for these new aquatic pests, zebra mussels. Study (Molloy, 1998) has shown that a strain of naturally occurring bacteria, *Pseudomonas fluorescens*, is selectively lethal to zebra mussels, but benign to fish and other bivalves. Experimental treatments have achieved up to 98 percent mussel kill, allowing power plants and other facilities to reduce or eliminate the use of chlorination, reducing the risk of potentially harmful effects of chlorine on aquatic ecosystems.

This model addresses a serious economic and environmental challenge with the development of an innovative biological control solution. The Zebra mussels' adaptation to chlorine and its effect on other aquatic animals is demonstrated in the model. Additionally, the model demonstrates the use of a bacteria-produced toxin for controlling Zebra mussel populations while not harming the rest of the ecosystem. This model is aimed at demonstrating the effect Zebra mussels have on power plant efficiency and the effects of chemical vs. biological control of these mussels. The model is based on Molloy's work (2002).

3.1.2. Goals

This model is aimed at answering the following questions:

1. Does mussel population size affect the power plant's efficiency?
2. Is the effect positive or negative?
3. Is chlorine treatment good for controlling mussel populations?
4. Is Bacteria-based bio-control more efficient than chlorination?

3.1.3. Assumptions

The model has been designed based on several assumptions drown from literature (Molloy, 2002):

1. The ecosystem contains one population of Zebra mussels, a ciliate population and one fish population.
2. Growth of the Zebra mussel population will negatively affect the cooling pipe efficiency of the power plant.
3. Chlorination leads to more mussel death when mussel adaptation to chlorine is low.
4. Fish and ciliates do not adapt to chlorine and are killed by it.
5. Ciliates feed on dead bacteria.
6. Bacteria population size increase leads to more mussel death.
7. Mussels do not adapt to bacteria.

3.1.4. Model components

The entity hierarchy of the model is presented in Figure 3.1.3. The structure is divided to 4 main groups, while 2 of them are divided to sub groups: ecological condition and population. The main entities involved are the "zebra mussels", "fish", "ciliate", "bacteria" and "power plant".

The power plant contains a cooling pipe and zebra mussel population. The ecosystem contains ciliates and fish.

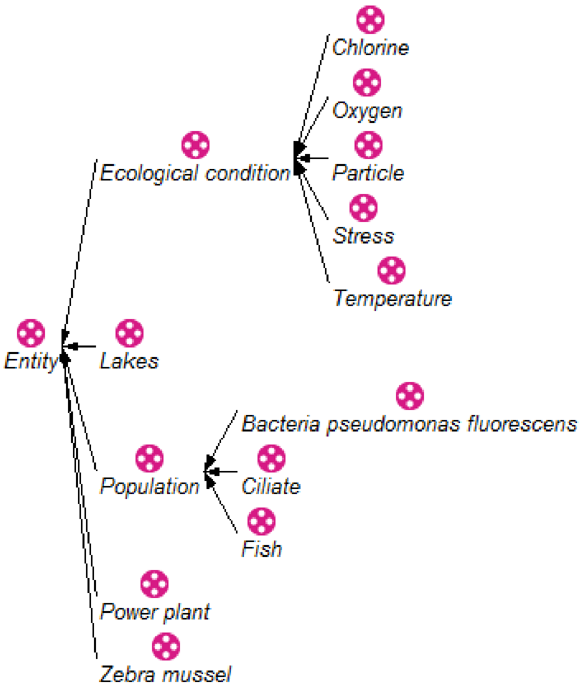


Figure 3.1.3. Entity hierarchy

Values in the Quantity Space (QS) are represents of the possible “qualitative states’’ of a quantity. The QS is a set of points and intervals. Determining the relevant quantity space for each quantity is an important aspect of constructing a qualitative model because it is one of the features that determines the variety of possible behaviours that will be found by the simulator when the model is simulated (Salles & Bredeweg, 2003). The model uses several QS depends on the entity. The considerations are explained in details in table 3.3.1. For example, The QS {Zero, Plus} describe different behaviour of the system: it indicates whether particular entities and/or processes are present. Table 3.1.1 describes the model components:

Table 3.1.1 Entity, quantity and quantity space of the model

Entity	**Quantity**	**Quantity space**	**Explanation**
Population (all populations)	Birth	Zero, plus	The reproduction rate of the population (if extinct the birth rate equals zero)
	Death	Zero, plus	The mortality rate of the population (if extinct the death rate equals zero)

	Number of	Zero, low, average, high	The number of individuals in a population. Four levels were chosen in order to better understand the system's dynamics (number of equals zero if extinct)
Zebra mussels	Resistance	Zero, plus, max	The resistance of the zebra mussels to chlorine (starting "zero" and while adjusting changes the resistance to "plus" or "max")
Pipes	Efficiency	Zero, low, average, high	The efficiency of the pipes to cool the power plants ("zero" means the pipe system is not helping to cool. 4 levels were chosen in order to better show the system's dynamics)
Chlorine Bacteria	Concentration	Zero, plus, max	The concentration of the chlorine (and also used for the bacteria).

3.1.5. Model fragments and scenarios

The model consists of several fragments (MF). The population growth fragment (MF3) Includes MF01 and MF01A (figure 3.1.4). The number of is influenced (I) by the birth rate (I+) and death rate (I-).

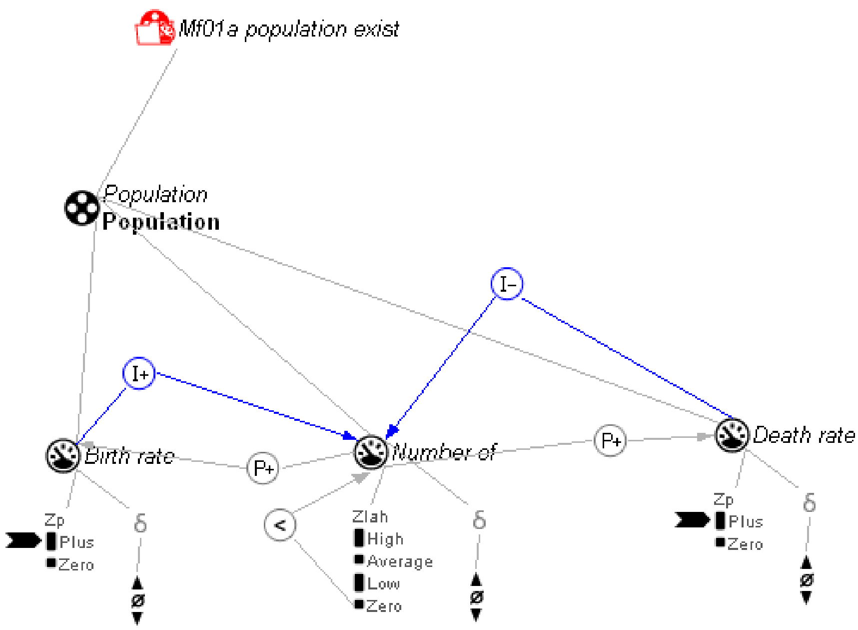


Figure 3.1.4. Population growth fragment

MF04 demonstrates the mussel effect on pipes. Number of mussels effects cooling pipe's efficiency as (P-) (reverse proportionality) (Figure 3.1.5).

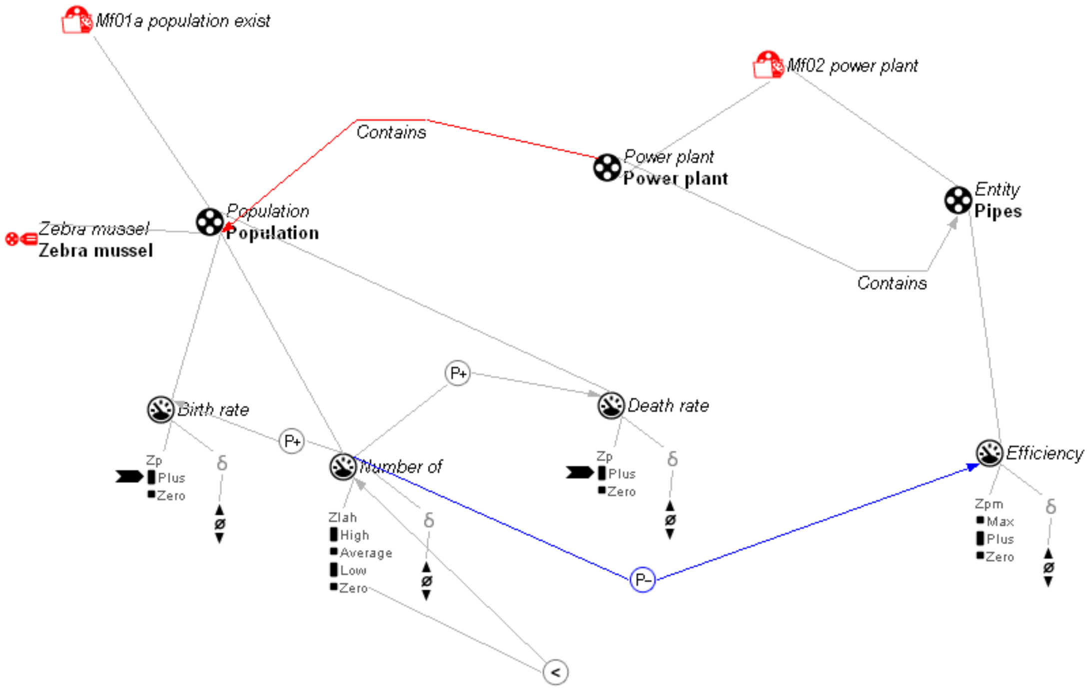


Figure 3.1.5 Number of mussels effects cooling pipe's efficiency

MF05 demonstrates the bacteria treatment (Figure 3.1.6). The bacteria concentration influences the birth rate of the ciliate (I+) and the death rate of the zebra mussels (I+).

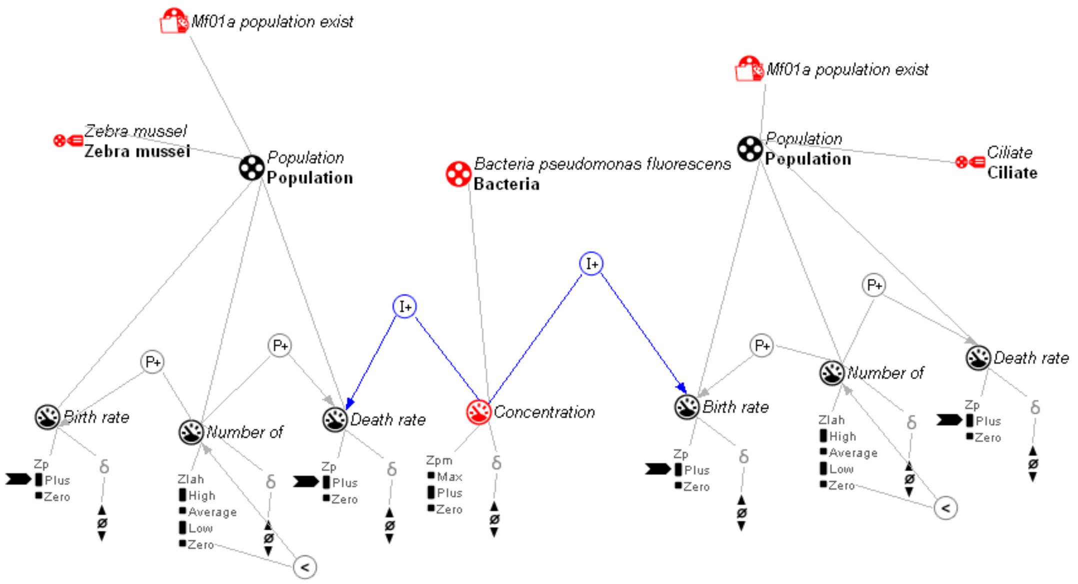


Figure 3.1.6 Bacteria treatment

MF06 and MF08 (in the case of the ciliate) demonstrates (Figure 3.1.7) how the chlorine concentration effects the death rate of fish (and ciliate) (I+).

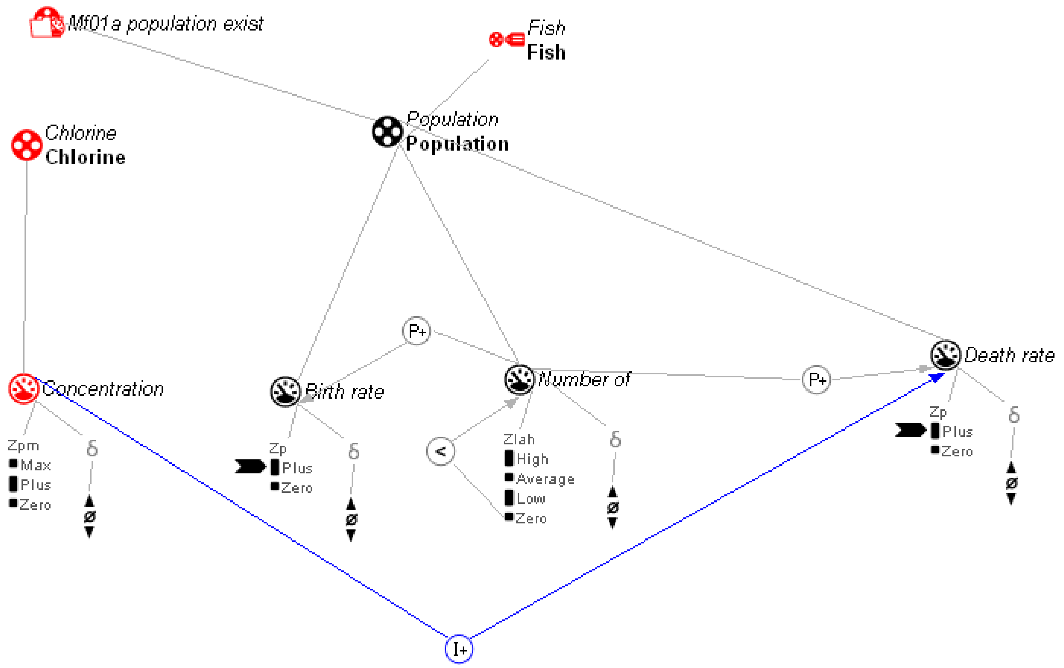


Figure 3.1.7 Chlorine influences the death rate of fish and ciliate

MF07A (Figure 3.1.8) demonstrates how the chlorine concentration effects (I+) the death rate of the mussels. Resistance to chlorine rises as chlorine concentration rises. When resistance is high chlorine no longer affects the mussels.

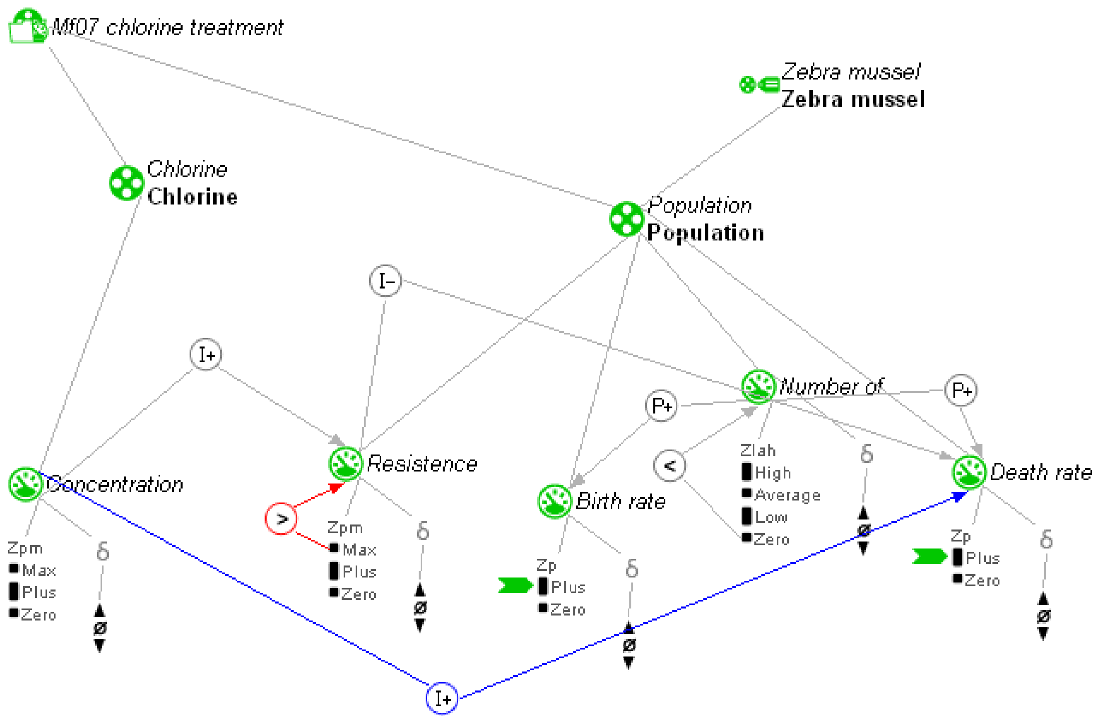


Figure 3.1.8 Low resistance of the zebra mussels to chlorine treatment

Table 3.1.2 summarizes the "after zebra mussel's invasion" scenario and simulation.

Table 3.1.2 "After invasion" scenario

Scenario name	After mussel invasion
Full simulation	11
Initial states	3
End states	6: [2],[4],[6],[7],[9],[11]
Relevant behaviour path	[3],[5],[8],[10],[11]
Behaviour description	Increase in mussel population leads to decrease in pipe efficiency

As seen in the simulation path (Figure 3.1.9), Increase in mussel population (number of) leads to decrease in pipe efficiency leading to a problem in the cooling system.

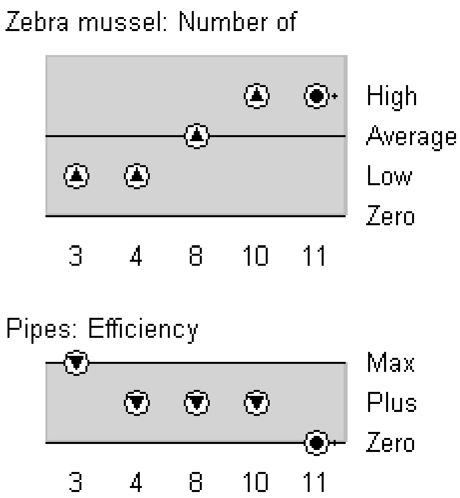


Figure 3.1.9 the mussel invasion simulation

Table 3.1.3 summarizes the "Chlorine treatment" scenario and simulation.

Table 3.1.3 "Chlorine treatment" scenario

Scenario name	With chlorine treatment
Full simulation	N/A
Initial states	1
End states	N/A
Relevant behaviour path	[],[2],[3],[4],[9],[33],[47],[59],[60],[61],[63]
Behaviour description	Chlorine concentration grows, fish population decreases to zero. Mussel resistance is low at first and population decreases, however as resistance becomes high population size increases

As seen in the simulation path (Figure 3.1.10), Chlorine concentration grows, fish population decreases to zero. Mussel resistance is low at first and population decreases, however as resistance becomes high population size increases.

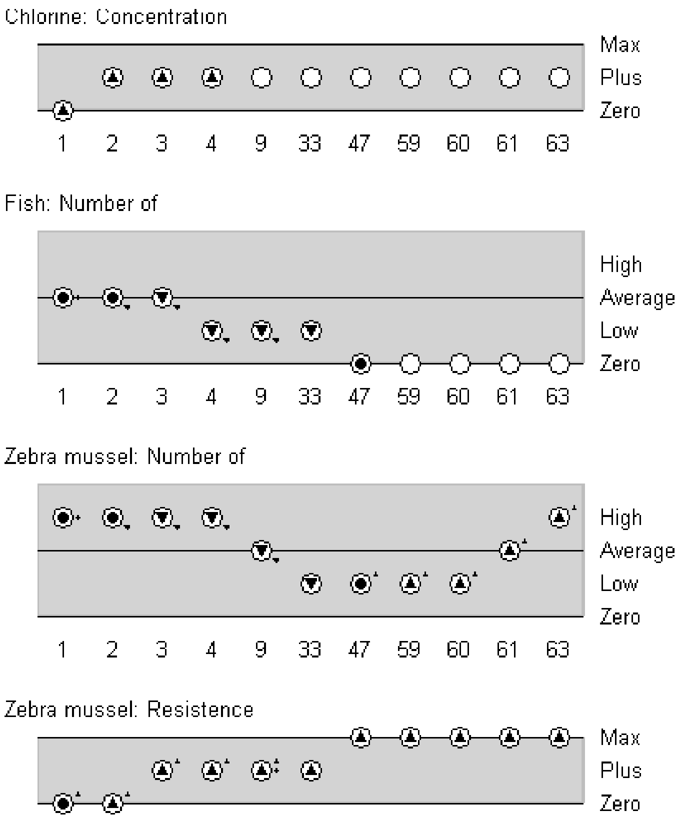


Figure 3.1.10 Chlorine treatment simulation path

Table 3.1.4 summarizes the "Bacteria treatment" scenario and simulation.

Table 3.1.4 "Bacteria treatment" scenario

Scenario name	With bacteria treatment
Full simulation	N/A
Initial states	3
End states	N/A
Relevant behaviour path	[3],[6],[9],[54],[66],[67],[73],[75]
Behaviour description	Bacteria concentration grows, ciliate population increases. Mussel population decreases to zero, pipe efficiency increases

As seen in the simulation path (Figure 3.1.10), Bacteria concentration grows and ciliate population increases. Mussel population decreases to zero and pipe efficiency increases.

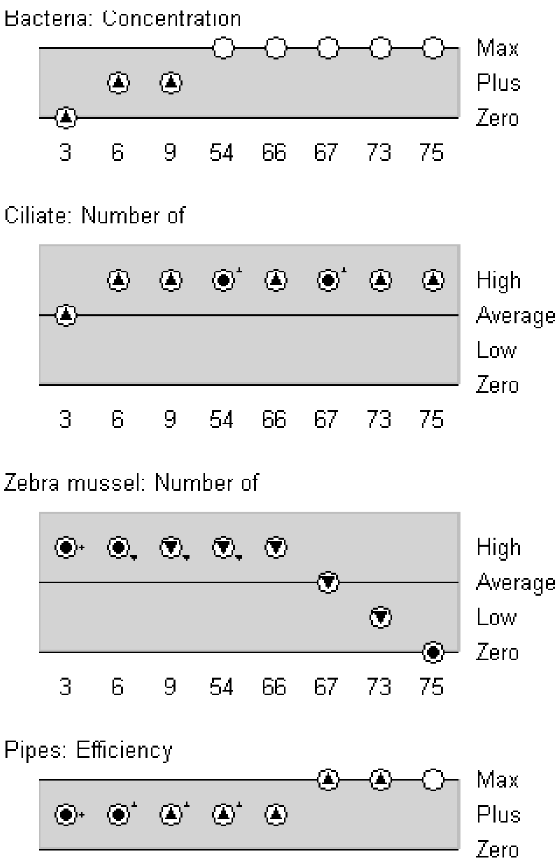


Figure 3.1.11 Bacteria treatment simulation path

3.2. Oil spill affecting a marine ecosystem

Theme / Topic	Pollution - The chemistry and physics of marine environments		
Author	Dror Zurel and Moshe Leiba	**Version(s)**	DL v0.8.5
Model	Oil spill - LS6		
Target users	Undergraduate students, high school students		

3.2.1. Background

In the open waters of the Gulf of Mexico, floating oil slicks and subsurface plumes threaten a highly diverse ecosystem. A 2009 inventory reveals that the area around the ill-fated rig hosts 1,728 species, among them whale sharks (see Figure 3.2.1), tarpon, tuna, sea turtles and sperm whales. Researchers are struggling to understand the scope and nature of the damage to deep-ocean ecosystems through some of the Gulf's largest residents (Gaskill, 2010).

The world's largest fish, whale sharks are filter feeders that subsist on fish spawn and plankton blooms — foods typically available off the Mississippi River delta in the summer. Direct contact with oil could fatally coat gills. Oil could reduce or contaminate plankton, the whale shark's primary food source.

Figure 3.2.1. Whale shark (*Rhincodon typus*) (l. Díaz romero/photolibrary). Retrieved from: http://www.nature.com/news/2010/100630/full/466014a.html

3.2.2. Goals

The model is aimed at demonstrating the effect of an oil spill on a marine ecosystem. Specifically, investigates the effects of an oil spill on a predator and prey population as a result of reducing the prey.

The model is aimed at answering the following question:

1. How does an oil spill affect predator-prey interactions?

3.2.3. Assumptions

The model has been designed based on several assumptions drown from literature (Gaskill, 2010):

1. The ecosystem contains one population of whale sharks that prey on a population of plankton.
2. An oil spill leads to a decrease in the plankton population.

3.2.4. Model components

The entity hierarchy of the model is presented in Figure 3.2.2. The structure is divided to 2 main groups, ecosystem and population. The main entities involved are the "plankton" and "whale shark" (an example to pray-predator interaction).

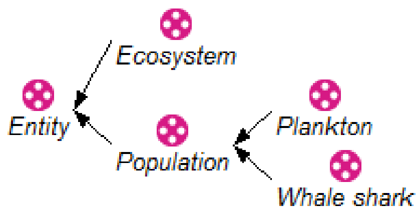


Figure 3.2.2. Entity hierarchy

Table 3.2.1 describes the model components:

Table 3.2.1. Entity, quantity and quantity space of the model

Entity	Quantity	Quantity space	Explanation
Population (all populations)	Birth	Zero, plus	The reproduction rate of the population (exist or non-exist)
	Death	Zero, plus	The mortality rate of the population (exist or non-exist)
	Number of	zero, low, average, high	The number of individuals in a population (4 levels were chosen in order to better view the system's dynamics)
Predator (whale shark)	Consumption	Zero, small, medium, large	The food consumption of the pray (whale shark).
Prey (plankton)	Supply	Zero, small, medium, large	The pray is being consumed by the predator (its supply).

3.2.5. Model fragments and scenarios

The model consists of several fragments (MF). The population fragment (MF01-4) describes an existing population (number of > zero) (figure 3.2.3). The number of is influenced (I+) by the birth rate and (I-) by death rate while the birth rate is proportional (P+) to number of and the death rate is proportional (P-) to number of.

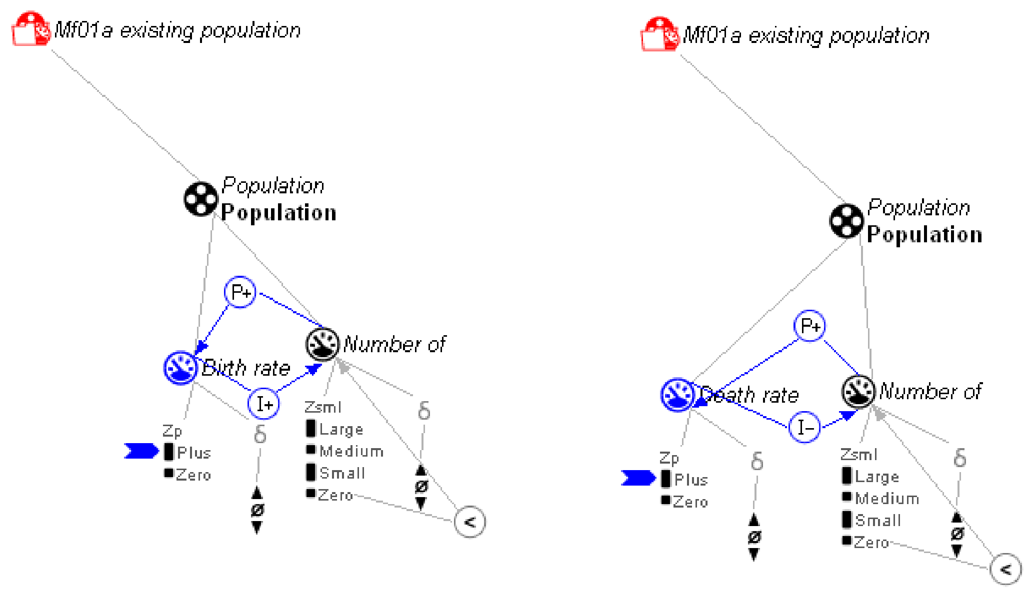


Figure 3.2.3. Population growth by processes of birth and death

MF05 (Figure 3.2.4) demonstrates the predation process. The predator's death rate is proportional (P-) to the supply (of the prey) and the prey's death rate is proportional (P+) to the predator's consumption.

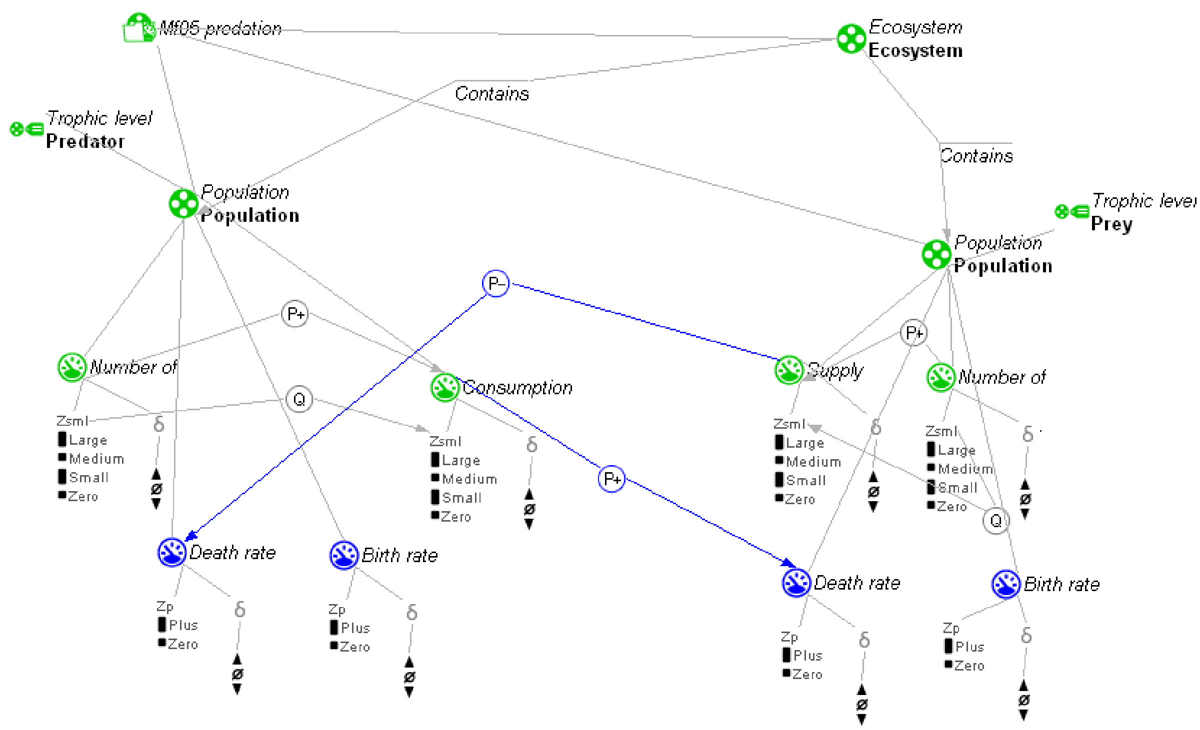


Figure 3.2.4. Supply and consumption affect death rates of predator and prey

MF06 (Figure 3.2.5) demonstrates how the oil spill affects the prey (plankton) population. The ecological system modeled was disturbed by an external agent (the oil industry) which caused an oil spill. The oil spill influences (I-) the number of the plankton (the pray).

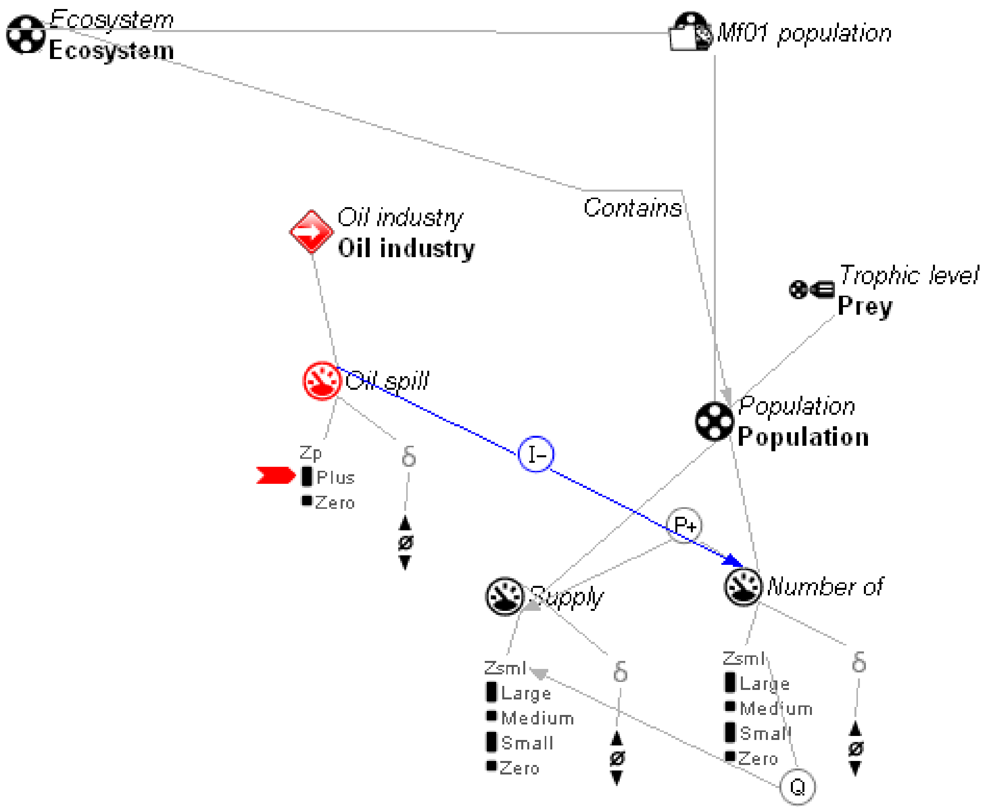


Figure 3.2.5. Oil spill affects the prey (plankton) population

Table 3.2.2 summarizes the "population dynamics" scenario and simulation.

Table 3.2.2 "Population dynamics" scenario

Scenario name	Population dynamics
Full simulation	34
Initial states	7
End states	16: [8],[9],[11],[12],[13],[14], [15],[18],[20],[23],[24],[26],[30],[31],[32],[34]
Relevant behaviour path	[1],[16],[25],[33],[35],[27],[26]
Behaviour description	Predator-prey dynamics. Decrease in plankton leads to decrease in whale shark, leading to increase in plankton

The simulation path (Figure 3.2.6) exhibits the predator-prey dynamics. Decrease in plankton leads to decrease in whale shark, leading to increase in plankton (part of a circular behavior).

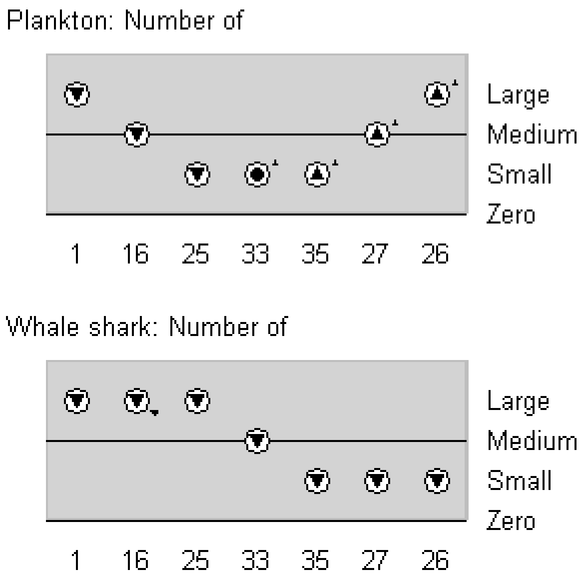


Figure 3.2.6 Population dynamics simulation path

Table 3.2.3 summarizes the "population dynamics with oil spill" scenario and simulation.

Table 3.2.3 "Population dynamics with oil spill" scenario

Scenario name	Population dynamics with oil spill
Full simulation	14
Initial states	1
End states	7
Relevant behaviour path	[1],[2],[7],[11],[12]
Behaviour description	Oil spill leads to decrease in plankton leading to decrease in whale shark

The simulation path (Figure 3.2.7) exhibits the predator-prey dynamics with an external agent (the oil spill). The oil spill leads to decrease in plankton leading to decrease in whale shark.

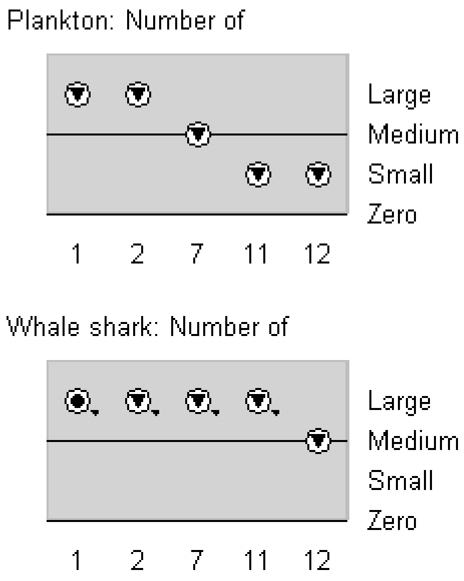


Figure 3.2.7 Population dynamics with oil spill simulation path

3.3. Nutrient upwelling

Theme / Topic	Energy Resources and Consumption - Biotechnological exploitation of marine organisms		
Author	Dror Zurel and Moshe Leiba	**Version(s)**	DL v0.8.5
Model	Nutrient upwelling - LS4		
Target users	Undergraduate students, high school students		

3.3.1 Background

Upwelling is an oceanographic phenomenon that involves wind-driven motion of dense, cooler, and usually nutrient-rich water towards the ocean surface, replacing the warmer, usually nutrient-depleted surface water (see Figure 3.3.1). The increased availability in upwelling regions results in high levels of primary productivity and thus fishery production. Approximately 25% of the total global marine fish catches come from five upwellings that occupy only 5% of the total ocean area (see Figure 3.3.2). Upwellings that are driven by coastal currents or diverging open ocean have the greatest impact on nutrient-enriched waters and global fishery yields[1].

Artificial upwelling is produced by devices that use ocean wave energy or ocean thermal energy conversion to pump water to the surface. Ocean wind turbines are also known to produce upwelling (Broström, 2008). Ocean wave devices have been shown to produce plankton blooms.

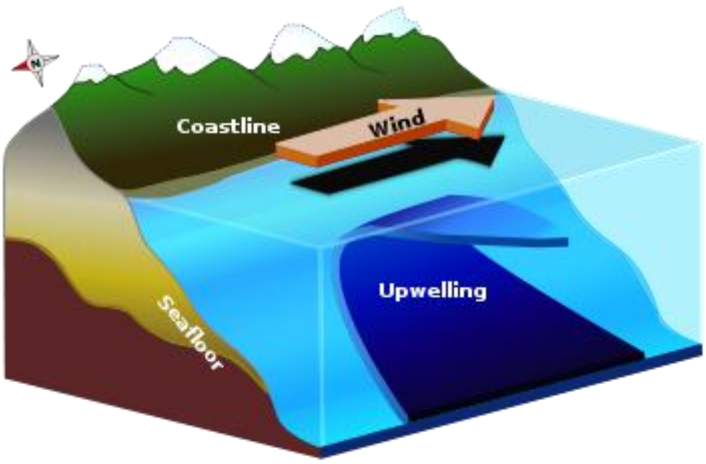


Figure 3.3.1. Upwelling - As surface water cools and sinks, nutrient-rich water rises from deeper levels to replace the surface water. Addition of nutrients leads to more primary production. Fish feed on the primary producers and their population grows. As more fish die they sink to the bottom and decompose, leading to a rise in nutrients in the deep again (retrieved from: http://en.wikipedia.org/wiki/File:Upwelling-labels-en.svg).

[1] http://en.wikipedia.org/wiki/Upwelling

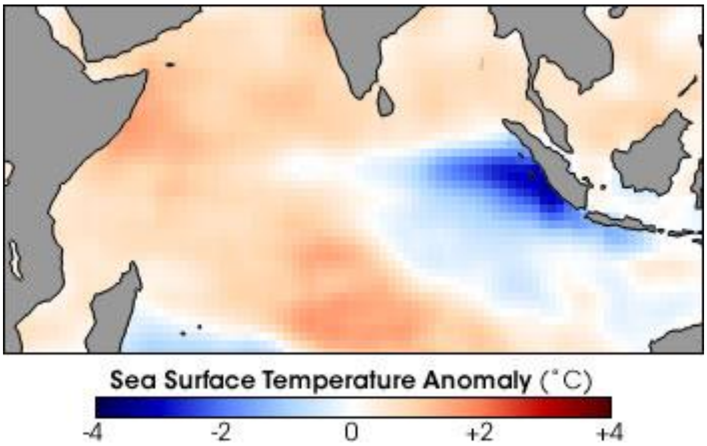


Figure 3.3.2. In this image blue areas are colder than normal, while red areas are warmer than normal (retrieved from: http://en.wikipedia.org/wiki/File:Sstanom_199711_krig.jpg)

3.3.2 Goals

This model is aimed at demonstrating the process of upwelling and its effect on the marine nutrient cycle.

The model is aimed at answering the following questions:

1. What role does upwelling play in the marine nutrient cycle?
2. What role do fish play in the marine nutrient cycle?
3. What role do bacteria play in the marine nutrient cycle?

3.3.3 Assumptions

The model has been designed based on several assumptions drown from literature (Broström, 2008):

1. Upwelling leads to a decrease in nutrients in deep water as they rise to shallow water.
2. Primary production requires nutrients in shallow water.
3. Fish require primary producers as a food source.
4. Bacteria decompose dead fish at the bottom, increasing nutrient concentration in deep water.

3.3.4. Model components

The main entities involved in the model are the "Nutrient-rich deep water", "surface water", "Fish" and "Bacteria".

Table 3.3.1 describes the model's components:

Table 3.3.1. Entity, quantity and quantity space of the model

Entity	Quantity	Quantity space	Explanation
Fish	Population size	Zero, low, average, high, max	The reproduction rate of the population
	Death rate	Zero, plus	The mortality rate of the population
Nutrient-rich deep water	Nutrient concentration	Zero, low, average, high, max	The nutrient concentration found at the deep level of the sea (zero to max)
	Upwelling	Zero, plus	The upwelling process (exist or non-exist)
Surface water	Nutrient concentration	Zero, low, average, high, max	The nutrient concentration found at the surface level of the sea zero to max)
	Primary production	Minus, zero, plus	The production of organic compounds at the surface level
Bacteria	Decomposing dead fish	Zero, plus	The decomposing of dead fish by the bacteria (happens or soes not happen)

3.3.5 Model fragments and scenarios

The model consists of 4 main entities (Figure 3.3.3). The upwelling influance (I+) the nutrient concentration of the surfacesurface water thus propgate the primary production (P+) and infuance (I+) the fish's population size.

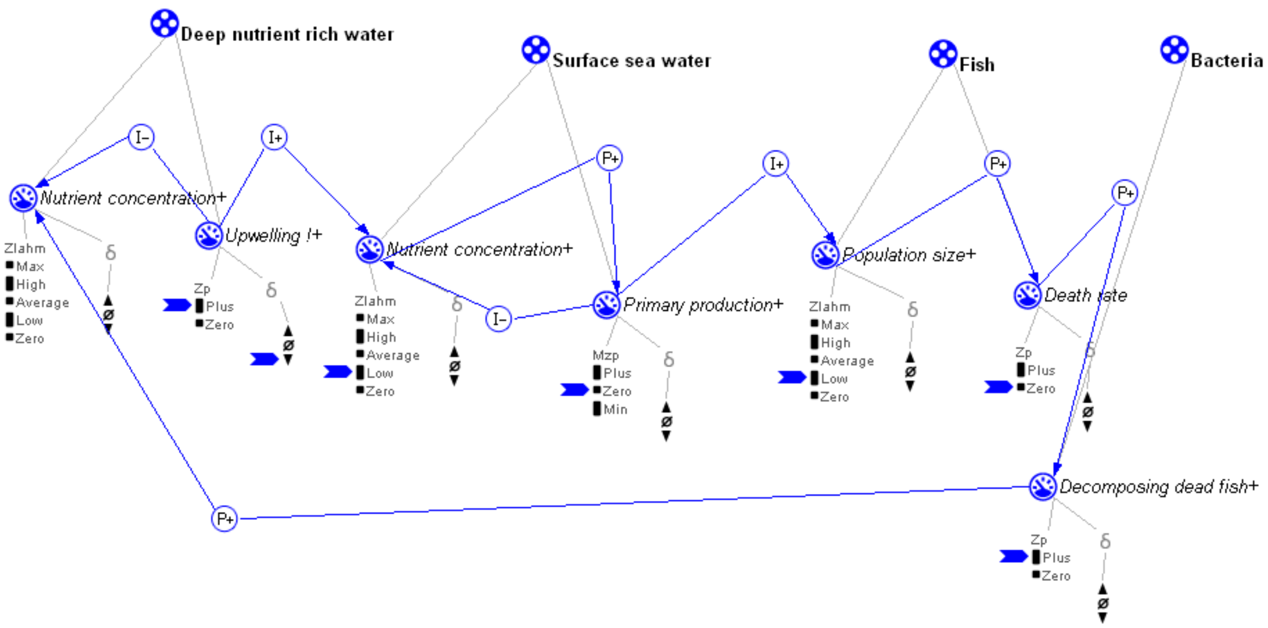


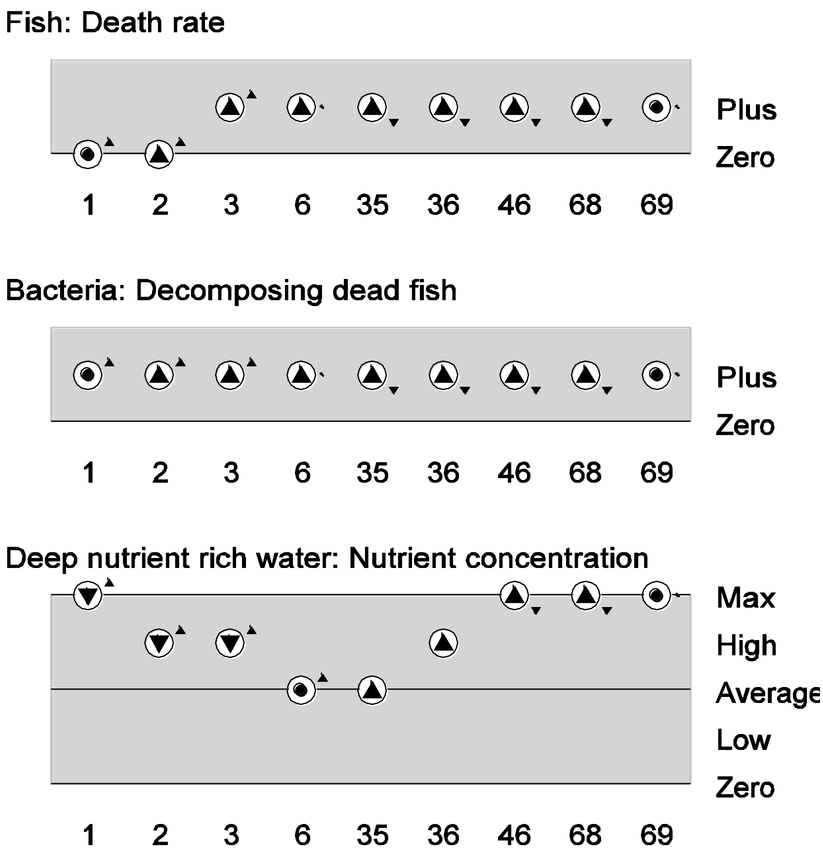
Figure 3.3.3. Nutrient upwelling model

Table 3.3.2 summarizes the "nutrient upwelling" scenario and simulation.

Table 3.3.2 "Nutrient upwelling" scenario

Scenario name	Nutrient upwelling
Full simulation	34
Initial states	1
End states	More than 70
Relevant behaviour path	[1],[2],[3],[6],[35],[36],[46],[68],[69]
Behaviour description	Upwelling leads to rise in shallow water nutrients and drop in deep water nutrients. Primary production increases leading to fish population size increase, then fish death and decomposing by bacteria, leading to rise in deep water nutrients

The simulation path (Figure 3.3.4) exhibits the upwelling dynamics. The upwelling leads to rise in shallow water nutrients and drop in deep water nutrients. The primary production increases thus leading to fish population size increase. The fish death and decomposing by bacteria, leading to rise in deep water nutrients (circular behavior).



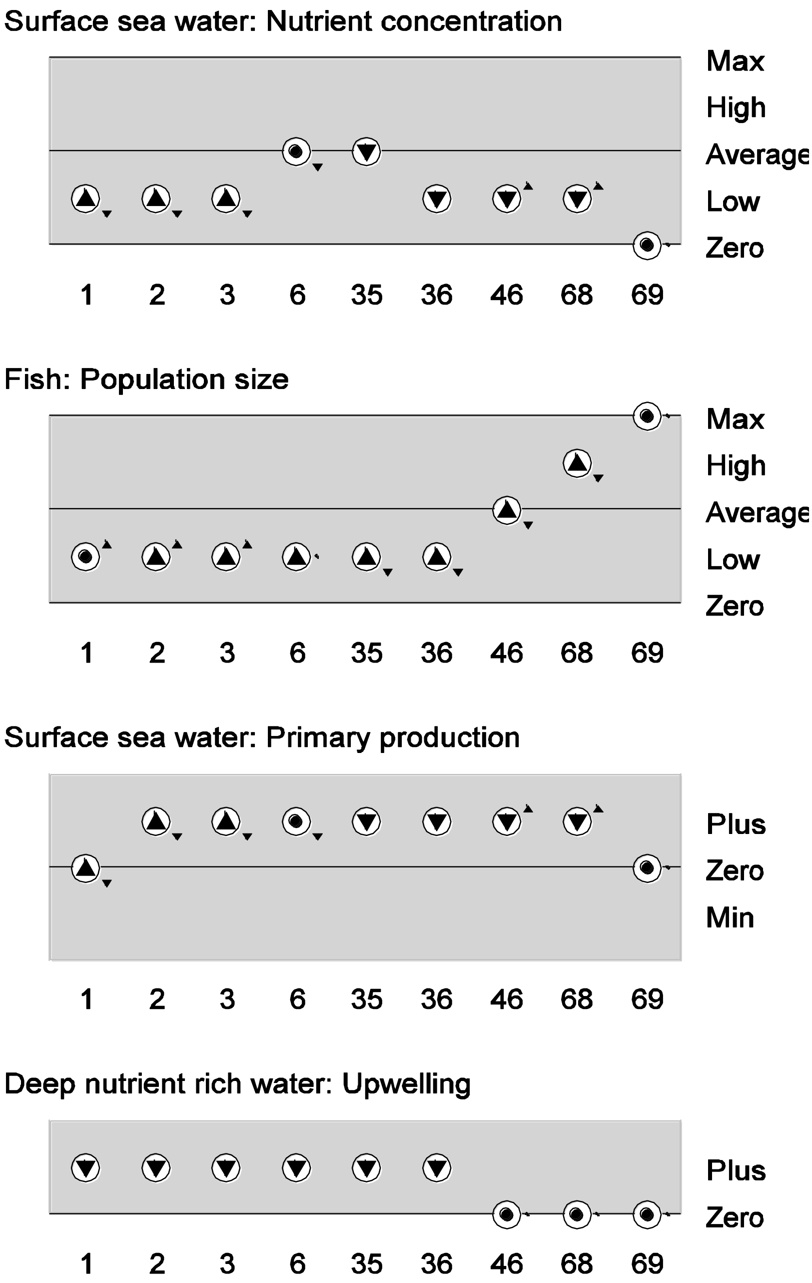


Figure 3.3.4. Nutrient upwelling simulation path

3.4. Coral reef global distribution

Theme / Topic	The Living World - Habitat dynamics		
Author	Dror Zurel and Moshe Leiba	**Version(s)**	DL v0.8.5
Model	Zebra mussel - LS6		
Target users	Undergraduate students, high school students		

3.4.1 Background

Coral reefs are underwater structures made from calcium carbonate secreted by corals. Coral reefs are colonies of tiny living animals found in marine waters that contain few nutrients. Most coral reefs are built from stony corals, which in turn consist of polyps that cluster in groups. The polyps are like tiny sea anemones, to which they are closely related. But unlike sea anemones, coral polyps secrete hard carbonate exoskeletons which support and protect their bodies. Reefs grow best in warm, shallow, clear, sunny and agitated waters (see Figure 3.4.1)[2].

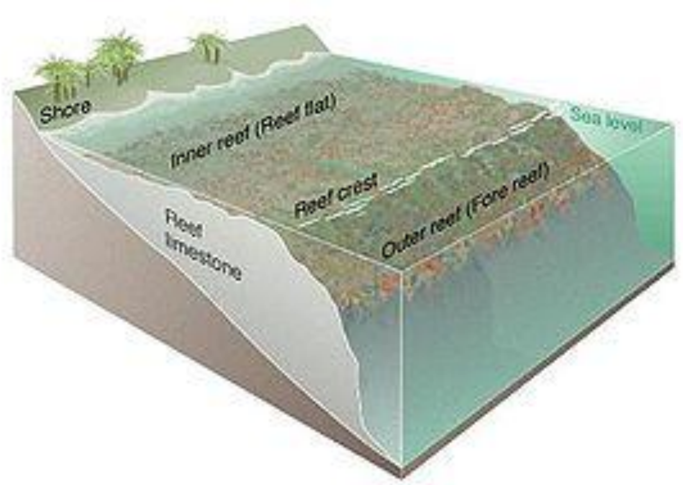


Figure 3.4.1. Colonial "hard corals" form elaborate finger-shaped, branching, or mound-shaped structures and can create masses of limestone that stretch for tens or even hundreds of miles (retrieved from: http://en.wikipedia.org/wiki/File:Coral_reef_diagram.jpg).

Coral reefs are estimated to cover 284,300 square kilometers, just under one tenth of one percent of the oceans' surface area. The Indo-Pacific region (including the Red Sea, Indian Ocean, Southeast Asia and the Pacific) account for 91.9% of the total coral reefs. Southeast Asia accounts for 32.3%, the Pacific (including Australia) accounts for 40.8% and the Atlantic and Caribbean coral reefs account for 7.6%.

While corals are found worldwide (see Figure 3.4.2), coral reefs are mainly found in tropical waters that have the conditions necessary for reef formation. Shallow-water reefs form only in a zone extending from 30° N to 30° S of the equator. Tropical corals do not grow at depths of over 50 meters. The optimum temperature for most coral reefs is 26–27 °C, and few reefs exist in waters below 18 °C (Achituv and Dubinsky, 1990). However, reefs in the Persian Gulf have adapted to temperatures of 13 °C in winter and 38 °C in summer.

2 http://en.wikipedia.org/wiki/Coral_reef

Figure 3.4.2. The areas that the Millenium Coral Reef Landsat Archive covers. Red dots indicate coral reef (retrieved from: http://en.wikipedia.org/wiki/File:Coral_reef_locations.jpg)

The model demonstrates the decrease in coral biomass as a factor of its proximity to the equator.

3.4.2 Goals

The model is aimed at demonstrating the effect of geographic location of coral reef formation. This model is aimed at answering the following questions:

1. What environmental conditions are needed to form a coral reef?
2. How do these conditions change when moving away from the equator?
3. How do these changes affect coral reef distribution?

3.4.3 Assumptions

The model has been designed based on several assumptions drown from literature (Buddemeier, 1997):

1. Distance from the equator leads to a decrease in a-biotic factors needed by corals and their symbiotic algae, leading to a decrease in coral biomass.
2. High coral biomass is needed to form a coral reef.

3.4.4 Model components

The entity hierarchy of the model is presented in Figure 3.4.3. The structure is divided to 6 main groups, while the a-biotic factors group is divided to 3 sub-groups. Abiotic factors affect coral reefs, corals live in coral reefs and algae are symbiotic with corals.

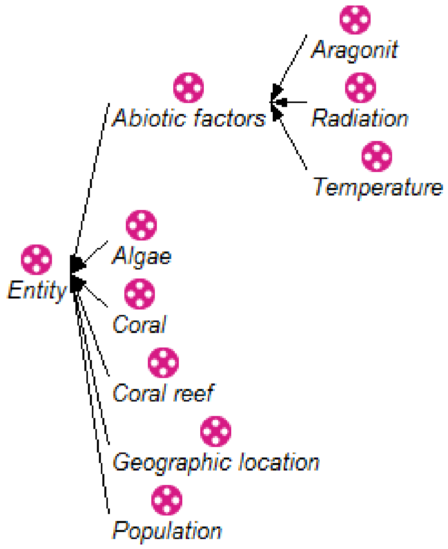


Figure 3.4.3. Entity hierarchy

Table 3.4.1 describes the model's components:

Table 3.4.1. Entity, quantity and quantity space of the model

Entity	Quantity	Quantity space	Explanation
Coral	Biomass	Zero, low, average, high	The biomass of the corals (4 levels were chosen to better explore the system's dynamics)
	Calcification rate	Zero, weak, plus, max	The calcification rate of the coral
Algae	Photosynthesis yield	Zero, weak, medium, high	The photosynthesis yield of the algae (4 levels were chosen to better explore the system's dynamics)
A-biotic factors	Temperature	Too cold, cold, warm, high	The temperature
	Radiation	Too low, low, mild, high	The radiation

	Calcium concentration	Low, medium, high	The calcium concentration
Dispersal	Travelling	From equator, zero, towards equator	The direction of traveling (3 QS representing the direction).
Latitude	Distance from equator	Very far, far, medium, close	The distance from the equator (4 levels were chosen to better explore the system's dynamics)

3.4.5 Model fragments and scenarios

The model consists of several fragments (MF). The A-biotic factors fragment (MF01) describes the correspondence between the temperature and the radiation (the a-biotic quantities) (Figure 3.4.4).

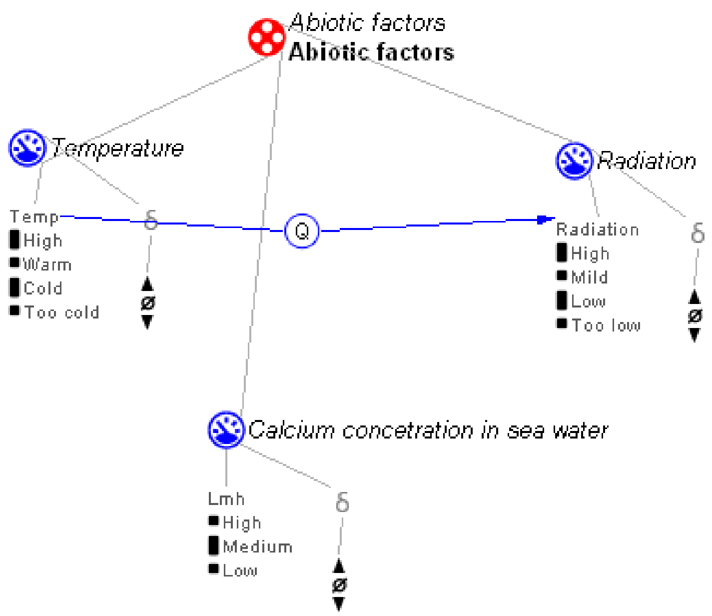


Figure 3.4.4. The A-biotic factors fragment

MF02 demonstrates the coral colony (Figure 3.4.5). The bacteria concentration influences the birth rate of the ciliate (I+) and the death rate of the zebra mussels (I+).

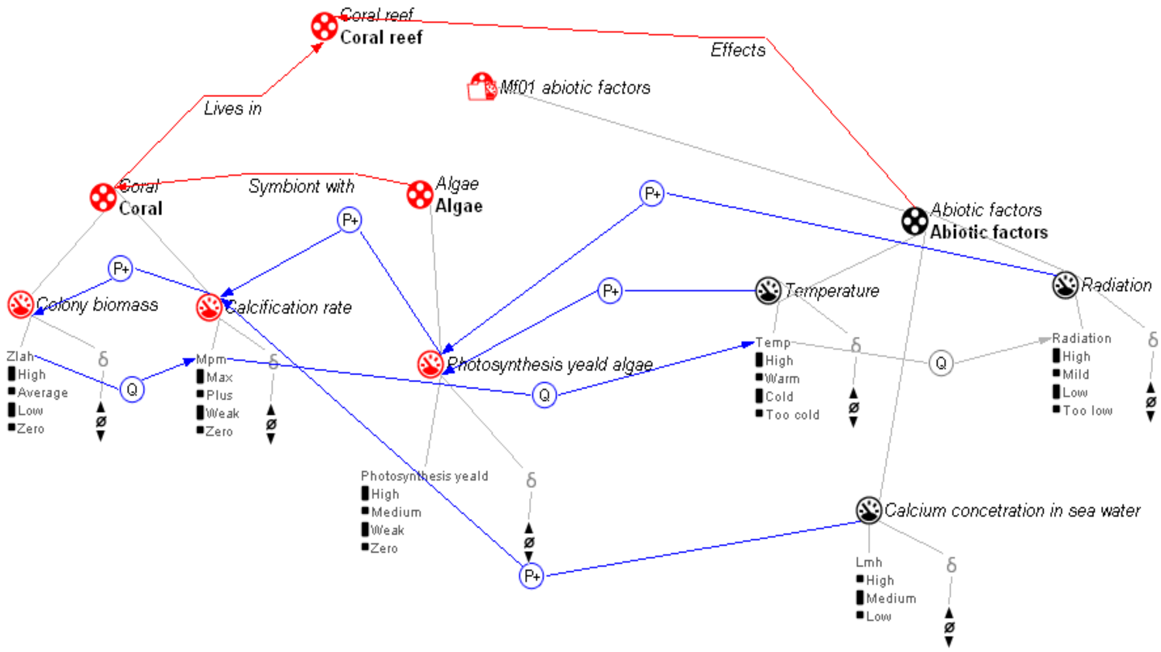


Figure 3.4.5. The coral colony fragment

MF03 demonstrates the dispersal (Figure 3.4.6). The traveling influence (I+) the distance from the equator.

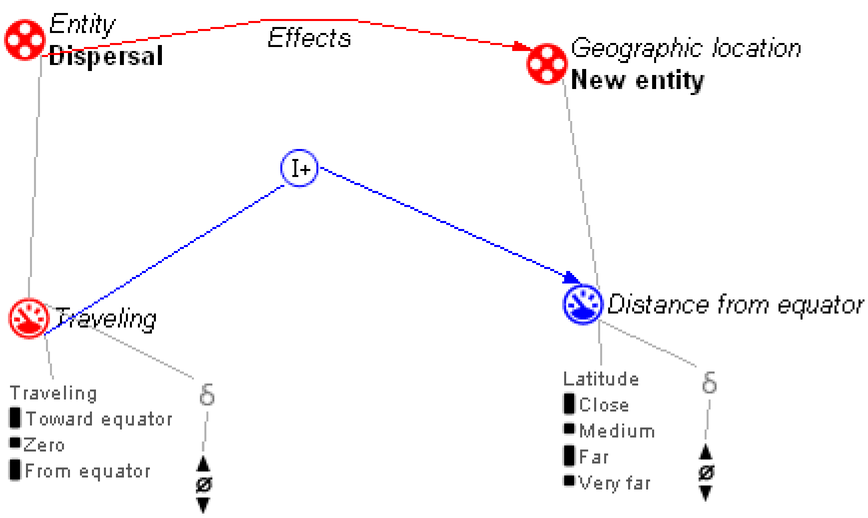


Figure 3.4.6. The dispersal fragment

MF04 demonstrates the Latitude (Figure 3.4.7). The distance from the equator propagates (P+) the temperature, the radiation and the calcium concentration (the a-biotic factors).

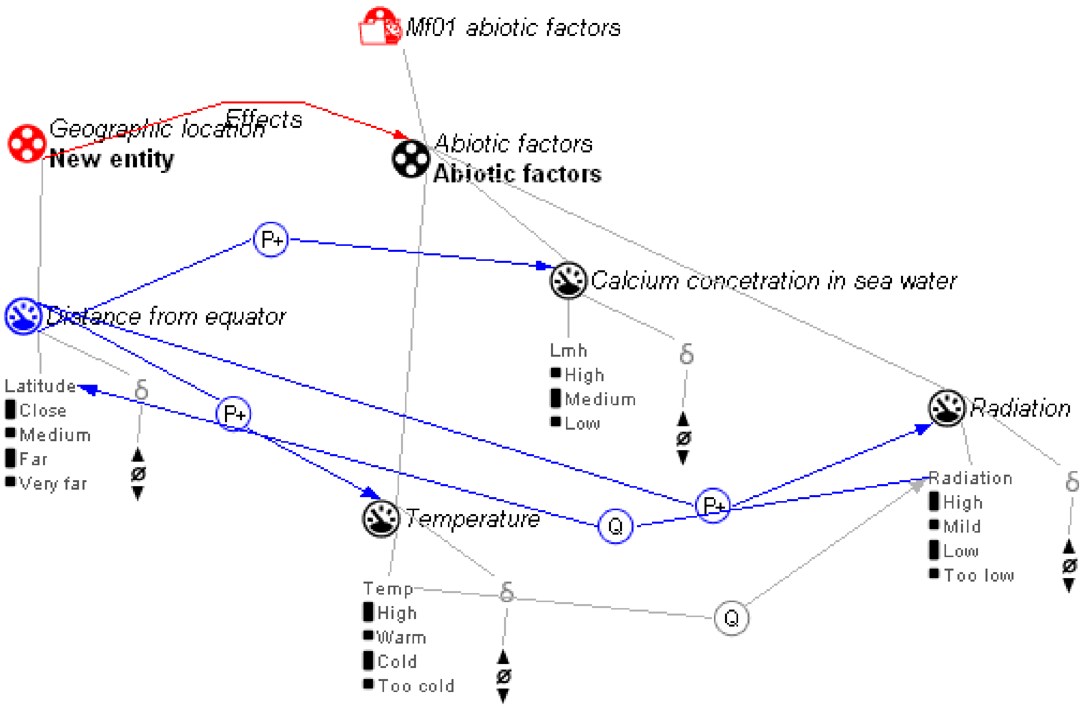


Figure 3.4.7.The latitude fragment

Table 3.4.2 summarizes the "coral reef distribution" scenario and simulation.

Table 3.4.2 "Coral reef distribution" scenario

Scenario name	Coral reef distribution
Full simulation	19
Initial states	1
End states	15
Relevant behaviour path	[1],[2],[8],[10],[19],[14],[15]
Behaviour description	The further the coral is from the equator, the a-biotic factors it needs to grow decrease, leading to low biomass

As seen in the simulation path (Figure 3.4.8), the further the coral is from the equator, the a-biotic factors it needs to grow decrease, leading to low biomass of the corals.

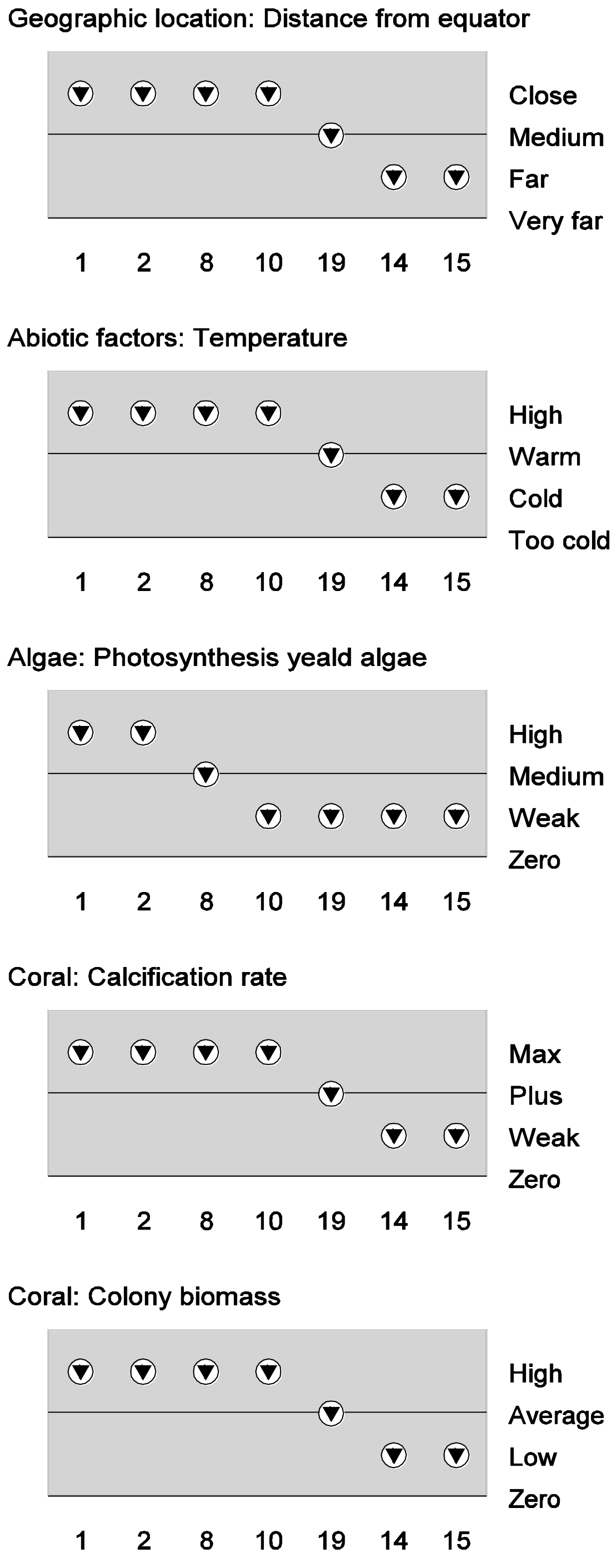


Figure 3.4.8. Coral reef distribution simulation path

3.5. Ocean warming and the nutrient cycle

Theme / Topic	Systems and resources - climate factors		
Author	Dror Zurel and Moshe Leiba	**Version(s)**	DL v0.8.5
Model	Nutrient cycle - LS6		
Target users	Undergraduate students, high school students		

3.5.1 Background

Marine phytoplankton, the vast range of tiny algae species (see Figure 3.5.1) accounting for roughly half of Earth's total photosynthetic biomass, have declined substantially in the world's oceans over the past 100 years (Boyce, Lewis and Worm, 2010). This adds to the concerns that climate change is dangerously altering marine ecosystems. Phytoplankton are the basis of the entire marine food chain, and have an important role in the global carbon cycle. Through photosynthesis, they produce around half of the oxygen in Earth's atmosphere and drive the 'biological pump' that fixes 100 million tons of atmospheric carbon dioxide a day into organic material, which then sinks to the ocean floor when the phytoplankton die, or are grazed and digested.

Phytoplankton activity fluctuates widely according to season and location, making long-term monitoring of trends difficult. Behrenfeld et al. (2006) suggested a link between climate variability and ocean productivity, but this was limited to observations from 1997 to 2006.

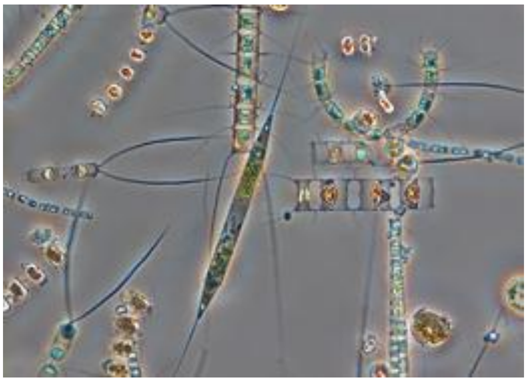


Figure 3.5.1. Since 1950, phytoplankton in the world's oceans have declined by 40% (Karl Bruun, Nostoca Algae Laboratory. Courtesy of Nikon Small World)

Research reveals an unsettling centennial downwards trend, superimposed on shorter-term variability. The scientists found that the average global phytoplankton concentration in the upper ocean currently declines by around 1% per year. Since 1950 alone, algal biomass decreased by around 40%, probably in response to ocean warming — and the decline has gathered pace in recent years. In most regions tested, the phytoplankton decline seems to be the result of a 0.5–1.0 °C warming of the upper ocean over the past century. The warming leads to enhanced vertical 'stratification' of ocean layers, thus limiting the supply of nutrients from deeper waters to the surface (Schiermeier, 2010).

The model shows the decline in phytoplankton populations in the oceans. Phytoplankton lives in the shallow waters and needs nutrients for primary production. Ocean warming leads to further layering of the ocean, as the shallow layer becomes warmer and does not mix with the cooler deep water. In winter the shallow water cools and mixes with the deep water, leading to upwelling of nutrients from the ocean bottom to the shallow water. As oceans become warmer, further layering will lead to less upwelling, leading to a decrease in nutrients in the shallow waters, thus leading to a decline in phytoplankton populations.

3.5.2 Goals

The model aimed at demonstrating the upwelling process and its importance to marine life. This model is aimed at answering the following questions:

1. How does upwelling affect the phytoplankton population?
2. How does ocean warming affect upwelling?

3.5.3 Assumptions

The model has been designed based on several assumptions drown from literature (Schiermeier, 2010):

1. The ecosystem contains one population of phytoplankton.
2. Upwelling leads to increase in shallow nutrient concentrations, leading to increase in phytoplankton population.
3. Ocean warming leads to further layering, leading to less upwelling.

3.5.4 Model components

The entity hierarchy of the model is presented in Figure 3.5.2. The structure is divided to 2 main groups, while the population group is divided to 2 sub-groups.

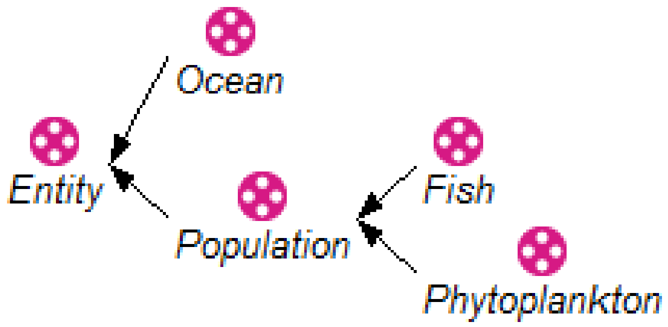


Figure 3.5.2. Entity hierarchy

Table 3.5.1 describes the model's components:

Table 3.5.1 Entity, quantity and quantity space of the model

Entity	Quantity	Quantity space	Explanation
Population	Birth	Zero, plus	The reproduction rate of the population
	Death	Zero, plus	The mortality rate of the population
	Number of	Zero, low, average, high	The number of individuals in a population
Ocean	Shallow nutrient concentration	Zero, low, average, high	The nutrient concentration in the shallow water
	Temperature	Zero, low, average, high	The temperature of the water
	Vertical layering	Minus, zero, plus	The vertical layering
	Upwelling	Zero, plus	The upwelling (happens or not)
Warming agent	Rate	Zero, plus	The warming rate (as an agent)

3.5.5 Model fragments and scenarios

The model consists of several fragments (MF). The population fragment (MF02-3) describes an existing population (number of > zero) (figure 3.5.3). The number of is influenced (I+) by the birth rate and (I-) by death rate while the birth rate is proportional (P+) to number of and the death rate is proportional (P-) to number of.

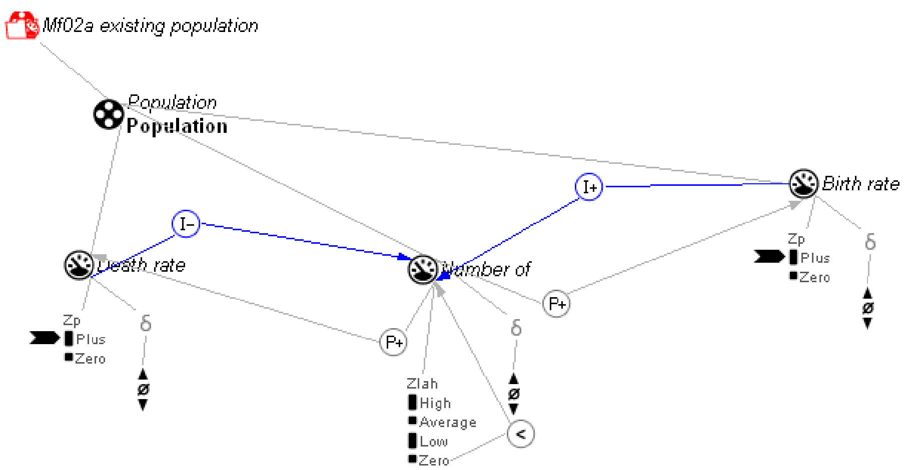


Figure 3.5.3. Population fragment

MF01 demonstrates the ocean's upwelling (Figure 3.5.4). The vertical layering influences (I+) the upwelling.

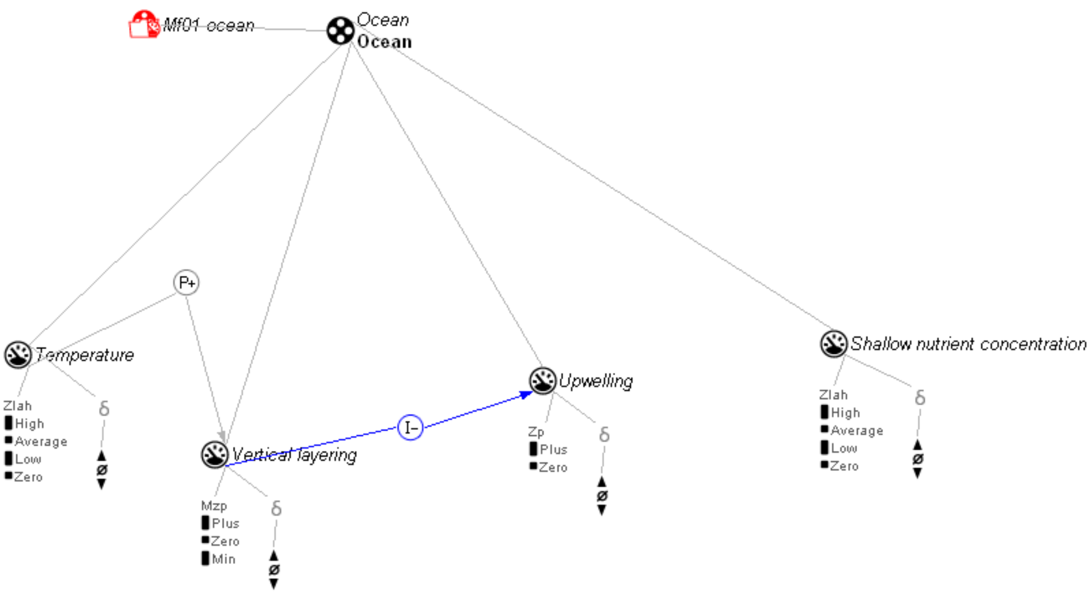


Figure 3.5.4. The upwelling fragment

MF04 demonstrates the nutrient cycle (Figure 3.5.5). The shallow nutrient concentration propagates (p-) the death rate of the phytoplankton.

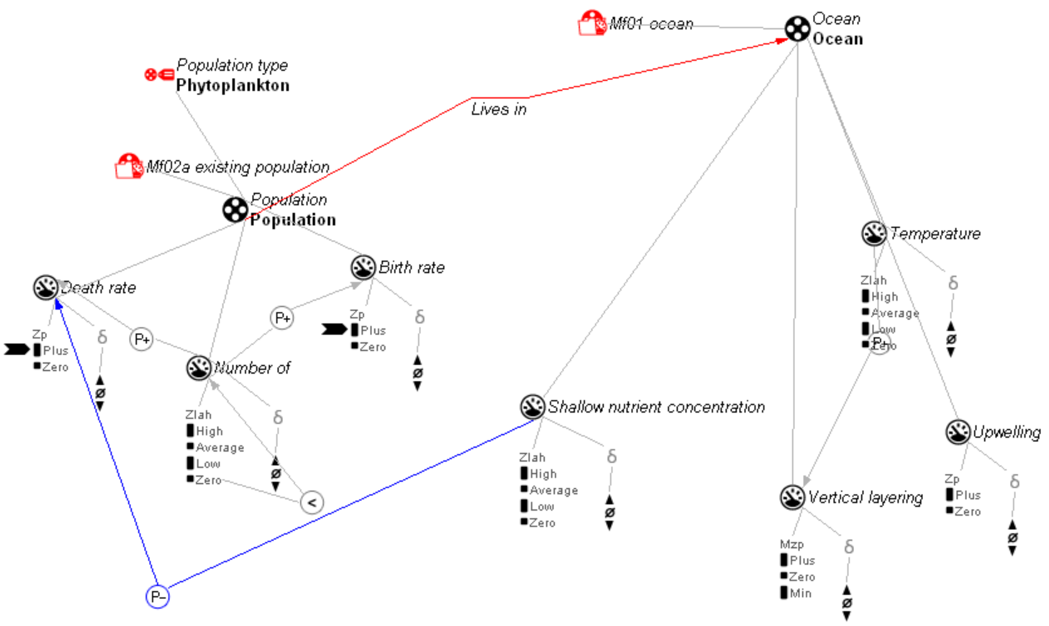


Figure 3.5.5. The nutrient cycle fragment

MF06a demonstrates the warning agent (Figure 3.5.6). The warming rate (at plus) influences (I+) the temperature. The upwelling propagates (P+) the shallow nutrient concentration.

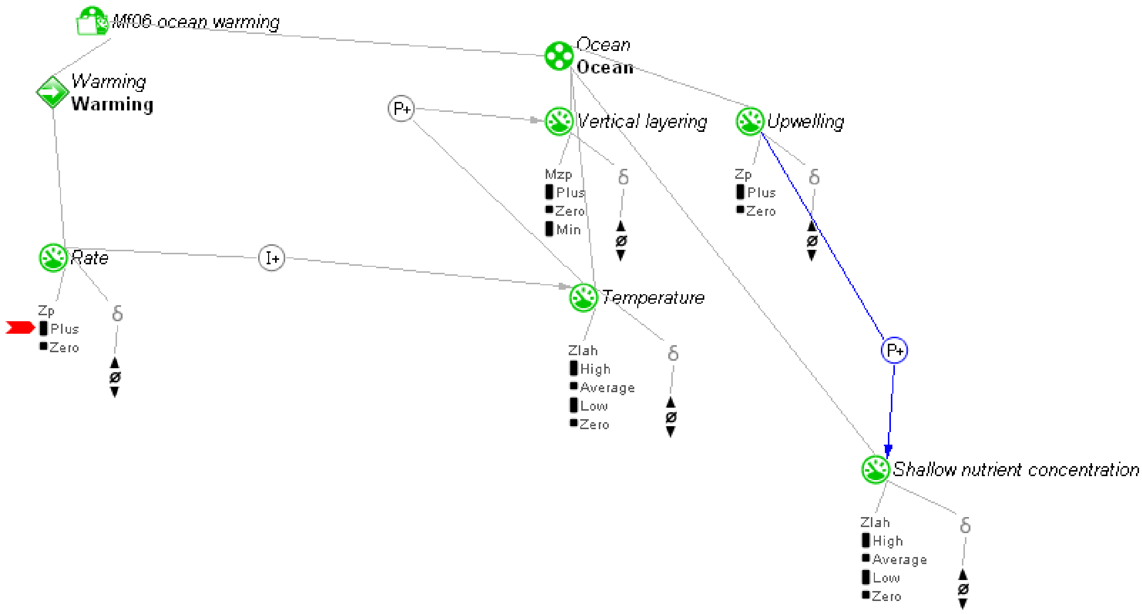


Figure 3.5.6. The warming agent fragment

MF06b demonstrates the process when there is no warning (Figure 3.5.7). The warming rate isat zero. The upwelling influences (I+) the shallow nutrient concentration.

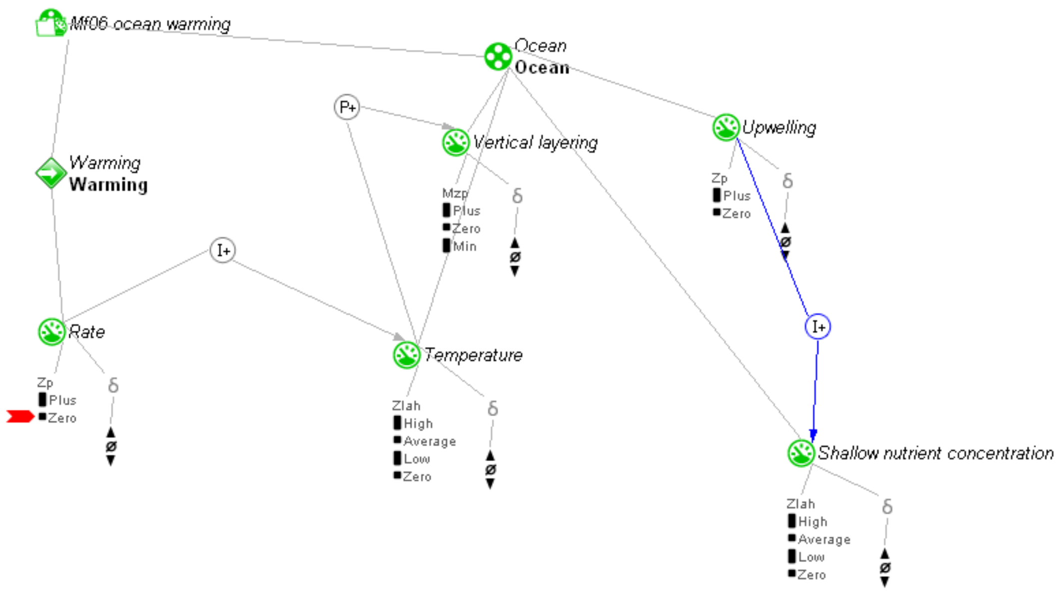


Figure 3.5.7. The warming agent fragment (agent = zero)

Table 3.5.2 summarizes the "ocean warming" scenario and simulation.

Table 3.5.2 "ocean warming" scenario

Scenario name	Ocean warming (agent=zero)
Full simulation	29
Initial states	5
End states	3: [17],[22],[23]
Relevant behaviour path	[1],[8],[12],[19],[26],[18],[27],[17]
Behaviour description	Temperature does not increase, layering remains zero, and upwelling occurs and leads to rise in nutrients, leading to rise in phytoplankton

As seen in the simulation path (Figure 3.5.8), the temperature does not increase, the layering remains zero, upwelling occurs and leads to rise in nutrients, leading to rise in phytoplankton.

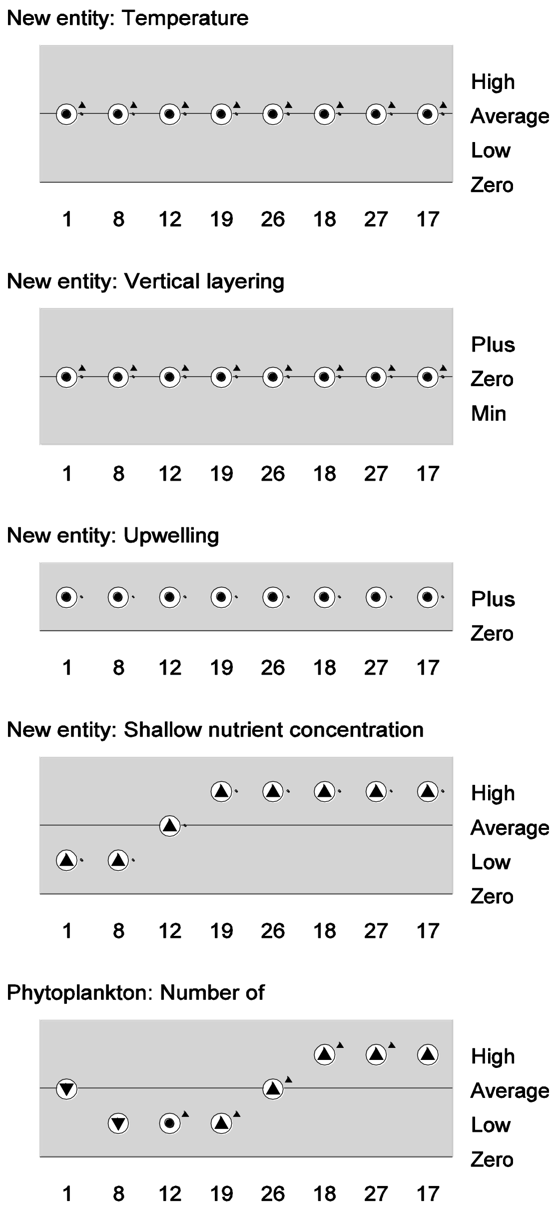


Figure 3.5.8. Ocean warming simulation path

Table 3.5.3 summarizes the "Ocean warming" scenario and simulation.

Table 3.5.3 "Ocean warming" scenario

Scenario name	Ocean warming (agent=plus)
Full simulation	9
Initial states	3
End states	3: [4],[7],[9]
Relevant behaviour path	[2],[5],[8],[9]
Behaviour description	Warming leads to layering, upwelling does not occur, nutrients decline and phytoplankton declines

As seen in the simulation path (Figure 3.5.9), the warming leads to layering, upwelling does not occur, nutrients decline and phytoplankton declines.

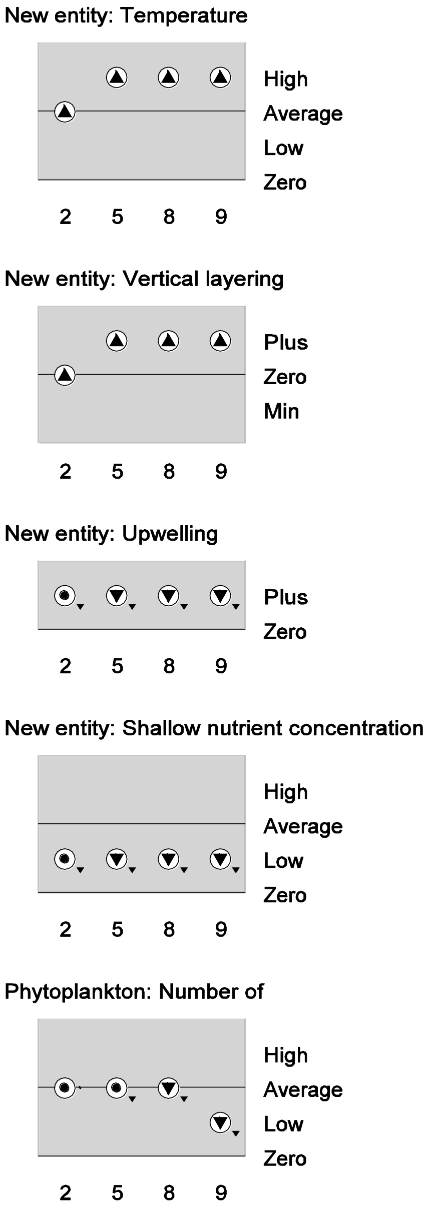


Figure 3.5.9. Ocean warming (with agent) simulation path

3.6. Carbon capture and toxic blooms

Theme / Topic	Energy, resources and consumption - Primary production		
Author	Dror Zurel and Moshe Leiba	**Version(s)**	DL v0.8.5
Model	Toxic blooms - LS6		
Target users	Undergraduate students, high school students		

3.6.1 Background

It has been previously suggested that adding iron to the oceans will lead to algal bloom that, through photosynthesis, help suck up atmospheric carbon dioxide. However, the extra iron was found to spark blooms of toxic plankton (Vastag, 2010).

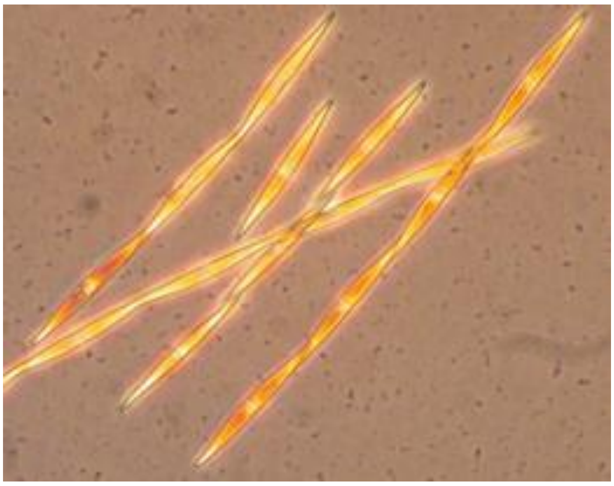


Figure 3.6.1. Fertilizing the oceans with iron could spark the growth of toxic *Pseudonitzschia* (*B. Bill/ NOAA).*

An algal bloom is a rapid increase or accumulation in the population of algae (typically microscopic) in an aquatic system. Algal blooms may occur in freshwater as well as marine environments. Typically, only one or a small number of phytoplankton species are involved, and some blooms may be recognized by discoloration of the water resulting from the high density of pigmented cells. Although there is no officially recognized threshold level, algae can be considered to be blooming at concentrations of hundreds to thousands of cells per milliliter, depending on the severity. Algal bloom concentrations may reach millions of cells per milliliter. Algal blooms are often green, but they can also be other colors such as yellow-brown or red, depending on the species of algae[3].

[3] http://en.wikipedia.org/wiki/Algal_bloom

Figure 3.6.2. Red tide is a term often used to describe toxic algal bloom in marine coastal areas (retrieved from http://en.wikipedia.org/wiki/Algal_bloom)

A few phytoplankton species are deadly. In suitable conditions they can grow and reproduce in great abundance, creating what is called a toxic bloom. They produce poisons that accumulate in the bodies of filter-feeding shellfish such as oysters, mussels, pipi and cockles. Usually the shellfish remain unaffected, but the fish, shore birds and marine mammals which eat them can be poisoned and die. The poisons cannot be destroyed by cooking, and in humans they can cause four nasty illnesses, which may result in paralysis, respiratory difficulty, memory loss or diarrhoea.

Trick et al. (2010) found neurotoxin domoic acid in samples of seawater from a site in the North Pacific, where iron-fertilization experiments have been conducted. Shipboard experiments by the team confirmed that adding iron increased production of the toxin by plankton of the genus *Pseudonitzschia*.

Domoic acid accumulates in shellfish and is a neurotoxin in birds and mammals, causing a condition called amnesic shellfish poisoning in humans. Blooms of *Pseudonitzschia* off the US west coast frequently prompt government agencies to shut down shellfish fisheries in the spring and summer. Scientists who study the blooms have blamed domoic acid for sea lion deaths, and they also speculate that the toxin may have caused an incident of frenzied bird behaviour in northern California in 1961.

This model is aimed at demonstrating how anthropogenic iron-enrichment of the ocean may lead to algal bloom which will reduce atmospheric Carbon Dioxide, but is also toxic to marine animals and to the humans who consume these animals.

3.6.2 Goals

This model is aimed at answering the following questions:

1. How does iron enrichment affect the alga population?
2. How does the algae population affect the Carbon Dioxide concentration?
3. How does the algae population affect other marine animals and human beings?

3.6.3 Assumptions

The model has been designed based on several assumptions drown from literature (Vastag, 2010):

1. Pseudonitzchia algae need iron to grow.
2. Pseudonitzchia algae assimilate CO2.
3. Pseudonitzchia algae create Domoic Acid which is toxic.

3.6.4 Model components

The entity hierarchy of the model is presented in Figure 3.6.3. The population group is divided to 2 sub-groups: shellfish and sea lions.

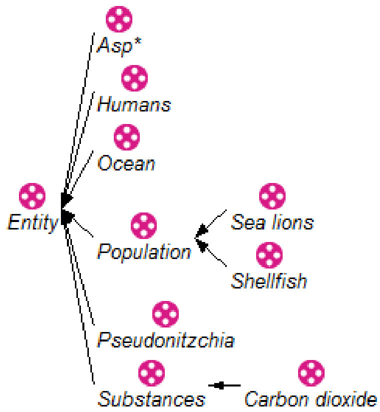


Figure 3.6.3. Entity hierarchy

Table 3.6.1 describes the model's components:

Table 3.6.1 Entity, quantity and quantity space of the model

Entity	Quantity	Quantity space	Explanation
Population (all populations)	Population size	Zero, low, average, high	The number of individuals in a population
	Growth rate	Minus, zero, plus	The growth rate of the population
Carbon dioxide	Concentration	Average, high	The concentration of the CO2 (starts at average)
Pseudonitzchia	Excretion rate	Zero, low, average, high	The excretion rate 4 levels were chosen to better explore the system's dynamics)
Ocean	Domoic acid	Zero, low,	The domoic acid concentration

	concentration	average, high	
Shellfish, sea lion and human	Accumulation level	Zero, low, average, high	The accumulation rate at humans, sea lions and shellfish
Amnesic shellfish poisoning (ASP)	Cases of	Zero, low, average, high	The cases of ASP 4 levels were chosen to better explore the system's dynamics)

3.6.5 Model fragments and scenarios

The model consists of several fragments (MF). The population fragment (MF02-3) describes an existing population (figure 3.6.4). The concentration level of domoic acid propagates (P+) the accumulation level in the population. The population size is proportional (P-) to the accumulation level.

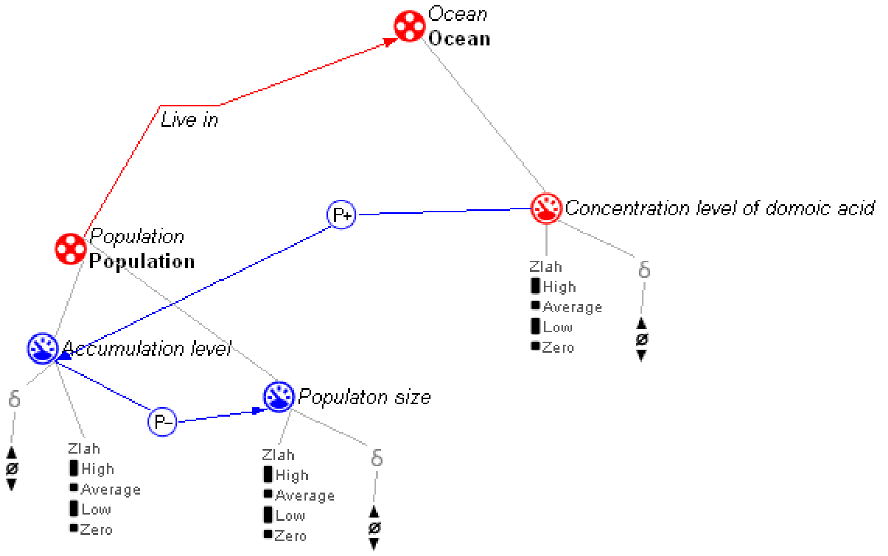


Figure 3.6.4. The population fragment

MF02 demonstrates the structure of the Pseudonitzchia entity (Figure 3.6.5). The population size propagates (P+) the excretion rate.

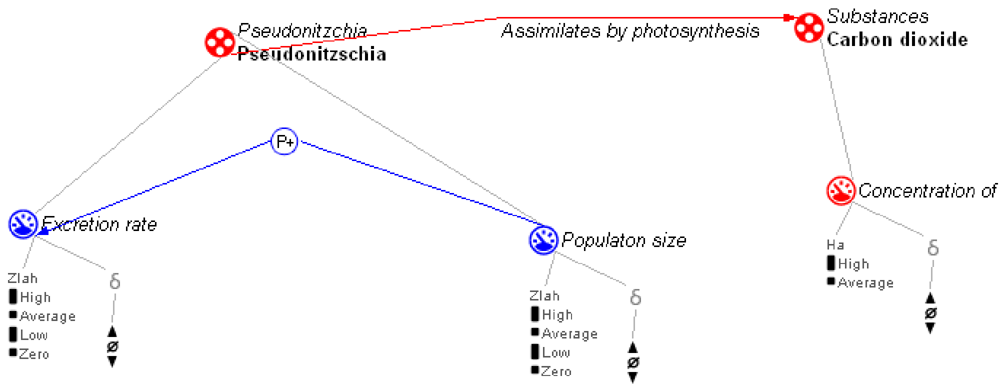


Figure 3.6.5. The Pseudonitzchia fragment

MF02 demonstrates the Amnesic shellfish poisoning (ASP) fragment (Figure 3.6.6). The accumulation level of the shellfish propagates (P+) the accumulation level of the humans thus propagates (P+) the cases of ASP.

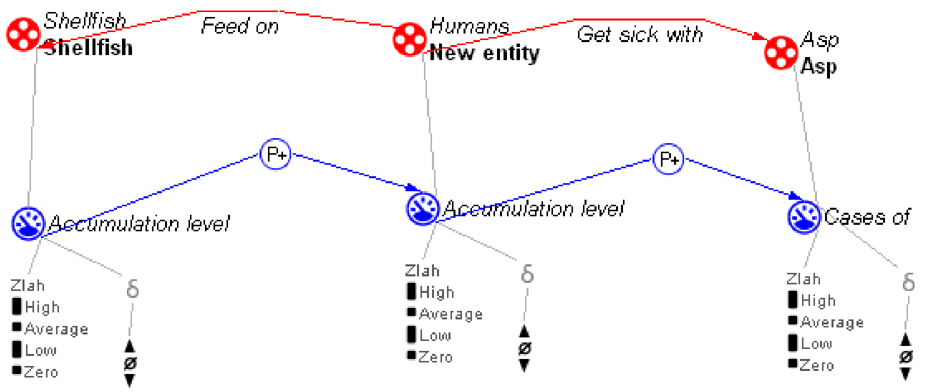


Figure 3.6.6. The Amnesic shellfish poisoning (ASP) fragment

MF04 demonstrates carbon dioxide cycle (Figure 3.6.7). The population size of the pseudonitzschia propagates (P-) concentration of CO2.

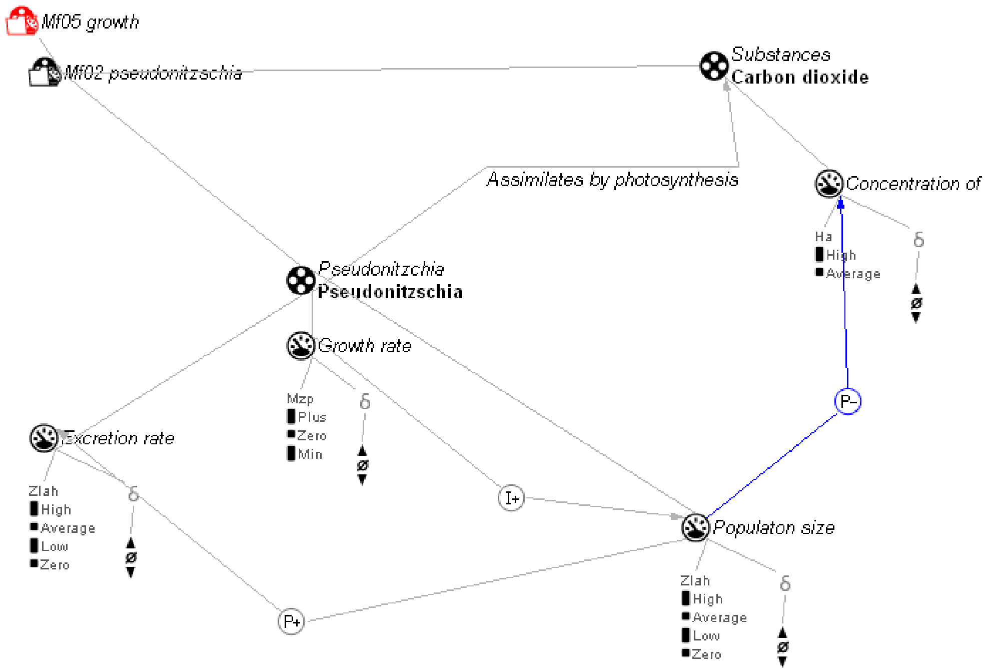


Figure 3.6.7. The carbon dioxide cycle fragment

MF05a demonstrates the growth of the pseudonitzschia (Figure 3.6.8). The growth rate influences (I+) the population size.

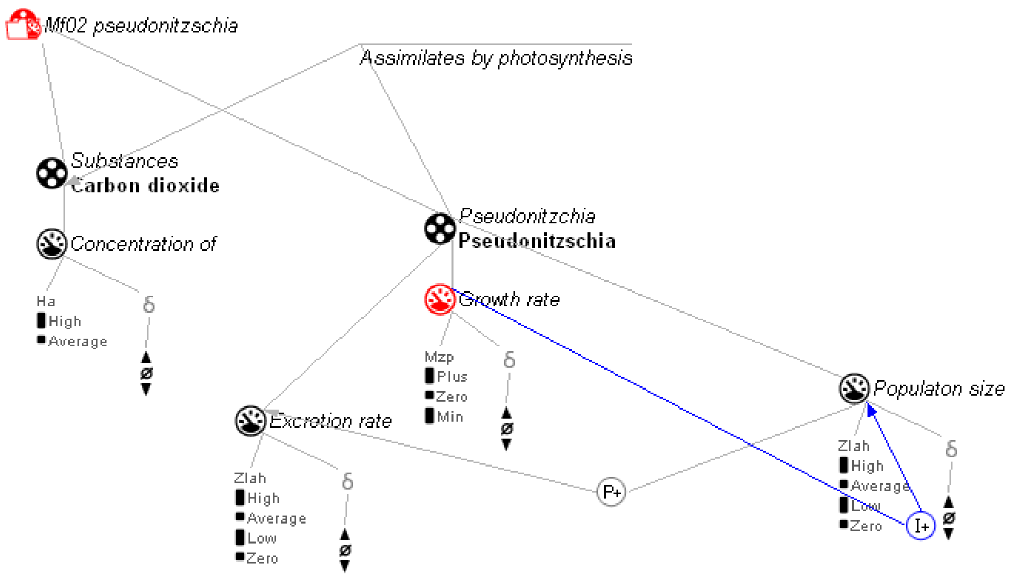


Figure 3.6.8. The growth fragment

MF05b demonstrates the toxicity (Figure 3.6.9). The excretion rate propagates (P+) the concentration level of domoic acid.

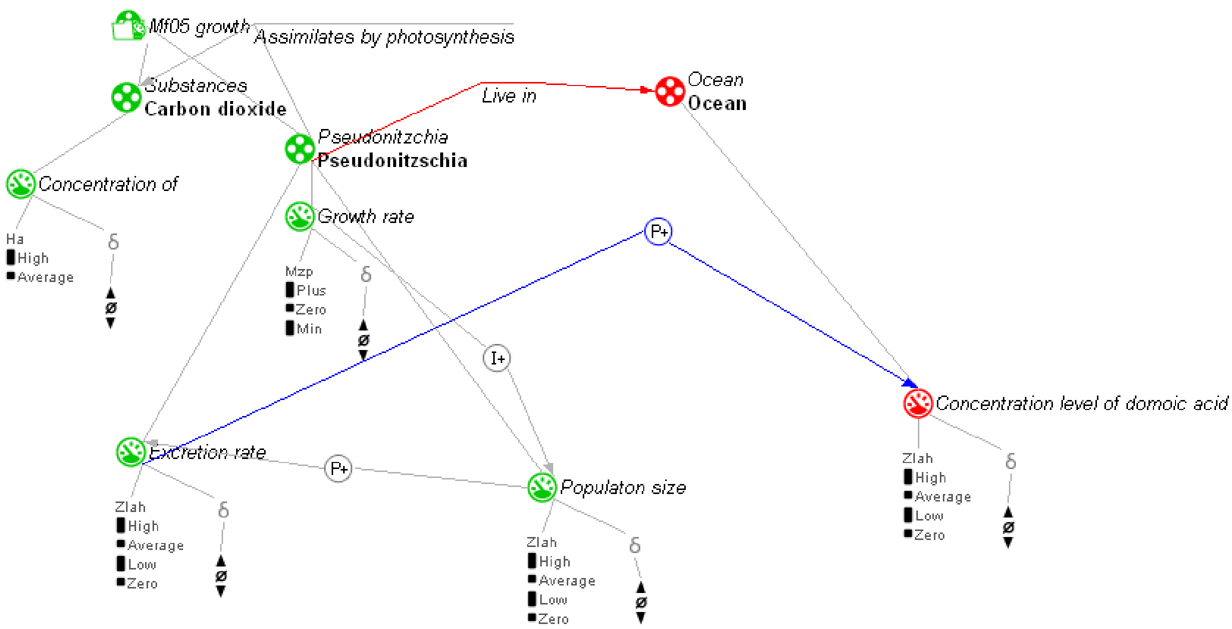


Figure 3.6.9. The toxicity fragment

MF06 demonstrates the iron enrichment process (Figure 3.6.10). The presence of iron (an external agent = plus) influences (I+) the growth rate.

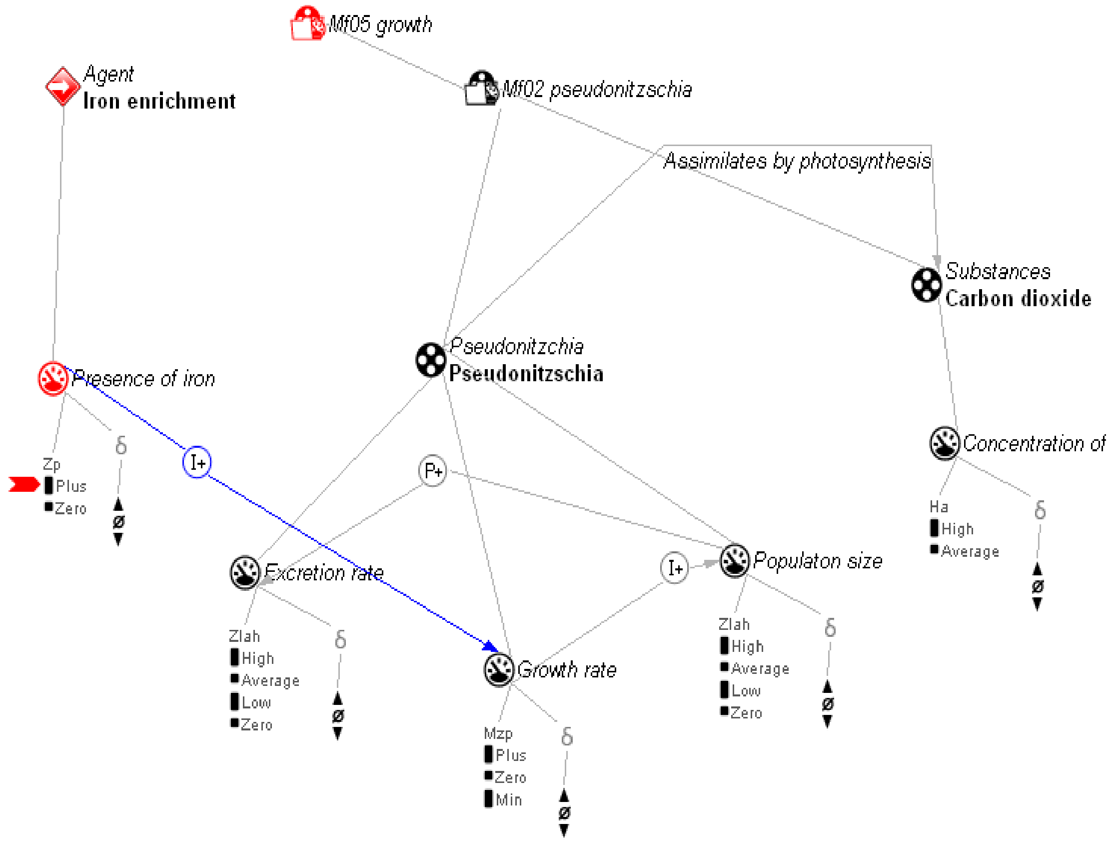


Figure 3.6.10. The iron enrichment (agent) fragment

Table 3.6.2 summarizes the "iron enrichment" scenario and simulation.

Table 3.6.2 "iron enrichment" scenario

Scenario name	Iron enrichment
Full simulation	56
Initial states	1
End states	1: [32]
Relevant behaviour path	[1],[2],[3],[13],[23],[45],[31],[33],[32]
Behaviour description	Iron enrichment leads to algal bloom, leading to increase in domoic acid levels, decrease in sea lion population and increase in ASP cases. It also leads to lower CO2 concentrations

As seen in the simulation path (Figure 3.6.11), the iron enrichment leads to algal bloom, leading to increase in domoic acid levels. This leads to a decrease in sea lion population and increase in ASP cases. It also leads to lower CO2 concentrations.

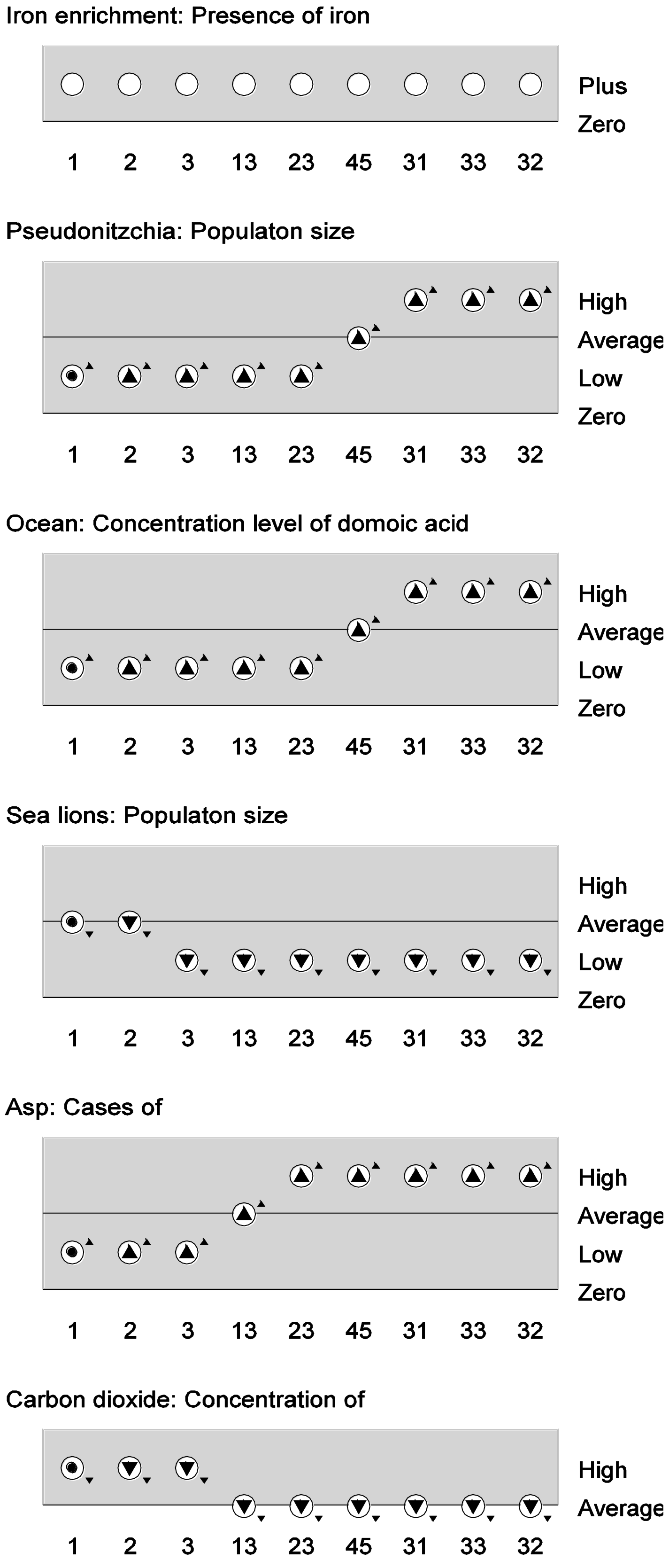


Figure 3.6.11. The iron enrichment simulation path

7. Discussion

This deliverable presents the second set of models (advanced models) developed at Tel Aviv University in correspondence with the curricular topics defined by the DynaLearn project and in accordance to the local Israeli curriculum in Environmental Science, area of Marine Biology, for undergraduate and high school students.

TAU's models cover 5 different topics associated to the main themes defined for DynaLearn's curriculum in Environmental Science. The models were designed at Learning Spaces 4 and 6 (LS4, LS6) provided in the DynaLearn workbench to enhance the potential for promoting learning. The models were implemented according to DL features at the different levels:

LS4 allows constructing a causal differentiation model. The modeller can differentiate between processes and quantities that propagate causality (Influences vs. Proportionalities). This enables models to be developed with qualitative causal relationships (e.g., see "Nutrient upwelling").

LS6 allows constructing a model using a generic and reusable knowledge. LS6 enables the modeller to use the knowledge in the model in separate model fragments. Different scenarios describe different initial situations of the system and enable to run different simulations. LS6 is the most complete model a modeller can construct, beginning with the definition of entities and quantities, defining causal relationships, reusing knowledge and interpreting the simulations.

The topics selected by TAU for modeling are of a major educational significance in the field of environmental sciences. They are engaged with subjects that are routinely taught in marine biology courses at the university level as well as in the high schools. Indeed, the models deal with specific cases however they represent core topics in marine environmental sciences. For example, Nutrient upwelling is a case study which is typical to inter specific interactions occurring in the marine environment. As competition is one of the major factors that shapes marine communities and as such modeling the outcome of such case has revealed intrigued scenarios. The increasing awareness of global change also in terms of global warming calls for novel educational approaches that foster unveiling the severe consequences of such change. As well, man-made impact on the environment in the form of chemical pollution (e.g. oil spill), biotechnological solutions (e.g. control of Zebra mussels using bacteria) have been integrated into environmental curricula and science education, yet their impact in some cases still remain rather vague. We strongly feel the qualitative reasoning approach embodied in the modeling process will enable the students to better grasp the above subject matters.

8. Conclusions

Following our modelling experience, we believe that the modelling process, in the case of a pedagogically-oriented tool as DynaLearn, is characterized by the need to integrate among three sets of considerations: Subject-matter and disciplinary considerations (scientific contents and definitions), the modelling approach and language (in this case QR and the tools offered by DynaLearn) and pedagogical considerations (e.g., the expected educational value of models in the different learning spaces, of different levels of complexity, or different levels of coverage of the modelled phenomena).

From our experience in the first and second phase of modelling we conclude that reaching a reasonable balance among these is important, for the progressive building of a repository in which its models are scientifically accurate, make appropriate use of the richness of the modelling environment of DynaLearn and clearly indicate their potential as resources to be integrated in lesson plans.

An additional and linked conclusion relates to the coverage of the curricular themes and topics included in DynaLearn's curriculum (see D6.1). Our modelling experience was inscribed within the broad context of the courses in Environmental Science we are involved in as part of our academic and research activities. Thus, besides serving as expert-models in the DynaLearn repository the models developed hold already immediate added value by their linkage to chapters and themes in the academic curriculum (at university and high school levels). At the curricular level, unveiling and clarifying these links will surely promote the integration of DynaLearn into regular educational settings.

Finally the insights gained during the modelling construction experience using the different tools at the different learning spaces have clear implications for the further planning of student modelling activities with DynaLearn. Considerations made about issues such as: the analysis and organization of the topic according to the modelling process requirements, to the tools and language being used, to the space of inquiry possibilities (often very wide) even for focused topics, etc. are of great value when coming to think about the planning of similar experiences by students. As well, identification of the resources of knowledge (including previous knowledge) demanded, skills required (modelling, reasoning with a modelling tool) at the highest Learning Space (LS6), etc. are helpful insights for the further making of pedagogical decisions.

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