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Abstract

This document presents the models developed in correspondence with the topics defined in DynaLearn's Environmental Science curriculum (D6.1). The topics covered for the different themes comprise: Earth systems and resources: Habitat dynamics; the living world: Species interactions and Community specific features; Pollution: The chemistry and physics of marine environments; Global changes: Adaptation to climate change in marine ecosystems; Human population: Biotechnological exploitation of marine organisms; Drinking water supply; Anaerobic respiration. The models were developed in the different Learning Spaces of the DynaLearn prototype workbench.

Acknowledgements

The authors would like to thank all partners in WP6 for their insights about the modelling process with DynaLearn, and the software development partners for their assistance during the modelling process. As well we want to thank to Michael Wissner and Rene Bühling for their helpful comments and suggestions in their review of this deliverable.

Document History

Version	Modification(s)	Date	Author(s)
01	First draft	2010-07-22	Zurel, Leiba, Benayahu, Mioduser
02	Second draft	2010-07-24	Zurel, Leiba, Benayahu, Mioduser
03	Deliverable for review	2010-07-25	Zurel, Leiba, Benayahu, Mioduser
04	Deliverable revised after review	2010-08-22	Zurel, Leiba, Benayahu, Mioduser

Contents

1. Introduction

This deliverable presents the first set of models (task 6.2) developed at Tel Aviv University in correspondence with the curricular topics defined in the deliverable D6.1.
TAU's models pertain to different topics associated to the 7 main themes 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.

2. Topics and models addressed in this deliverable

2.1. Context for the models developed

The current curricula on Environmental Science in Israel fosters 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 outreach activities among youngsters (elementary, junior high and high schools, gifted and low socioeconomic levels and minorities). The activities exposes 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, green architecture, 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 behavior 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, Beck, 2008; Bouduresque and Verlaque, 2002; Por, 2009; Rilov & Crooks, 2009).

2.2. Links to DynaLearn Curricula (D6.1)

The selected topics are presented in accordance to their relevance to environmental science curricula focusing on exploring marine systems, while taking the general DynaLearn curriculum based on the 7 themes as the basis:

Earth systems and resources (ESR)

- *Habitat dynamics* - to identify processes relevant for the creation and maintenance of habitat features, necessary to assure the survival of a specific population or community, and 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 (e.g., adaptation to invasion).

The living world (TLW)

- *Species interactions* - to model positive and negative interactions between different populations, and to use species interactions models to express relevant topics for understanding environmental phenomena, for example, decomposition of organic matter, trophic relations, nutrient cycling and energy flow (see: Gobi and shrimp).
- *Community specific features*- to model specific features of biological communities (e.g., species diversity, disturbance and resilience, complexity and succession), and to compare specific features of different biological communities (see: competition for space by two mussel species).

Human population (HP)

- *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. As well, to demonstrate that protection of biodiversity protection may improve the conditions of a particular society in a given situation described in a case study (see: diving pressure; overfishing).

Pollution (Poll)

- *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 behavior of the systems due to pollution. As well, 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: TBT and imposex).

Global changes (GC)

- *Adaptations to climate* change *in marine ecosystems* - to identify how climate factors influence the structure and behavior of populations, communities and the whole marine ecosystem and establish a web of causal relations that result in adaptive traits; to represent hypotheses about how human actions may improve or make worse the climate conditions that affect marine ecosystems in specific case studies (see: metabolism and acidity).

Land and Water use (LW)

- *Drinking water supply* - to identify and model processes in which water treatment procedures are applied with the aim to supply drinking water in regions deprived from this vital resource.

Energy resources and consumption (ERC)

- *Anaerobic respiration* - To identify the most relevant factors involved in anaerobic energy metabolism and to establish causal relations among them and the nutrient cycling and energy flow. To demonstrate biological and industrial applications of anaerobic respiration.

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

***Table 2.2** Summary of themes and topics from the D6.1 curricula in Environmental Sciences and the models covered in TAU D6.2.2.*

Theme	Topic	Sub-topic	LS01	LS02	LS03	LS04	LS05	LS06
ESR	Habitat dynamics	Adaptation to invasion						✓
TLW	Species interactions	Shrimp and Goby symbiosis		✓	✓	✓		
	Community specific features	Competition for space			✓			✓
GC	Adaptation to climate change in marine ecosystems	Metabolism and Acidity		✓				✓
Poll	The chemistry and physics of marine environments	TBT and Imposex		✓	✓	✓		✓
HP	Biotechnological exploitation of marine organisms	Diving pressure			✓			
	Biotechnological exploitation of marine organisms	Over fishing		✓	✓	✓		✓
LW	Drinking water supply	Reversed Osmosis for Sweetwater Desalination			✓			
ERC	Anaerobic respiration	Aerobic/anaerobic respiration			✓			

3. Models developed

3.1. Adaptation to invasion

Theme / Topic	***Earth systems and resources / Habitat dynamics***		
Author	***Dror Zurel***	***Version(s)***	***DL v0.6.11(CM)***
Model	***Adaptation to invasion - LS6***		
Target users	***Undergraduate students***		

The model is based on the following article:

Aaren S., Freeman, J., and Byers, E. (2006) Divergent Induced Responses to an Invasive Predator in Marine Mussel Populations. *Science* (313) 831-833

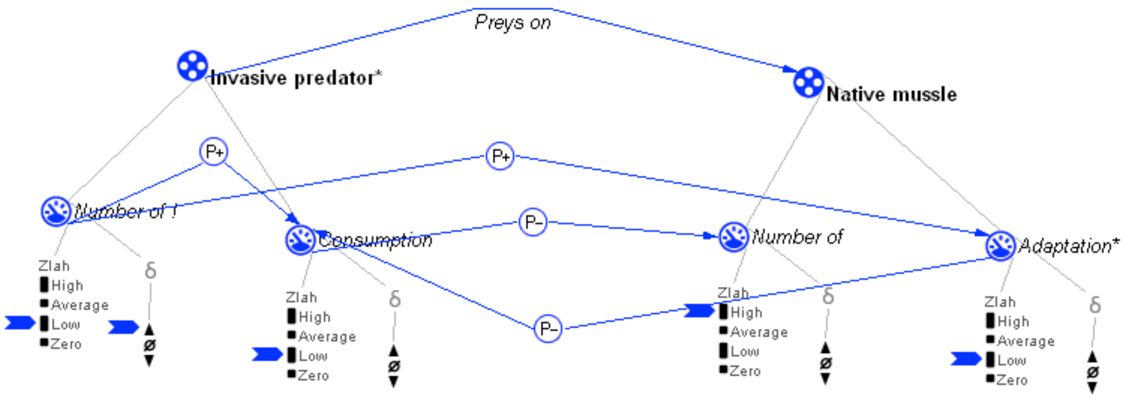
An invasive species is a species living outside its native distributional range, which has arrived to its new location by human activity, either deliberate or accidental. Introduced species have vast effects on the native flora and fauna, and they often out-compete the native species for resources such as food, nutrients and settlement grounds. An invasive predator may expose native prey to a new kind of threat, one it is not adapted to. Excess predation by the invasive predator may also damage the equilibrium between the indigenous predators and their prey, as the invasive predator out-competes the local ones. This equilibrium depends on the prey's ability to adapt itself to this new threat.

In this article, the invasive Asian shore crab, Hemigrapsus sanguineus, preys on mussels (Mytlius edulis). Mussels that have adapted to the predator crab express inducible shell thickening when exposed to waterborne cues from Hemigrapsus.

The model tests whether the adaptation rate, i.e. the thickening of the shell, is fast enough to slow down the predation rate until a new equilibrium is attained. The model demonstrates the adaptation of a native mussel to predation by an invasive predator crab. The model contains two population entities, the invasive crab and the native mussel. The model is a level 4 model and therefore has only one model fragment which also serves as a scenario.

3.1.1. Adaptation to invasion LS6

Structure



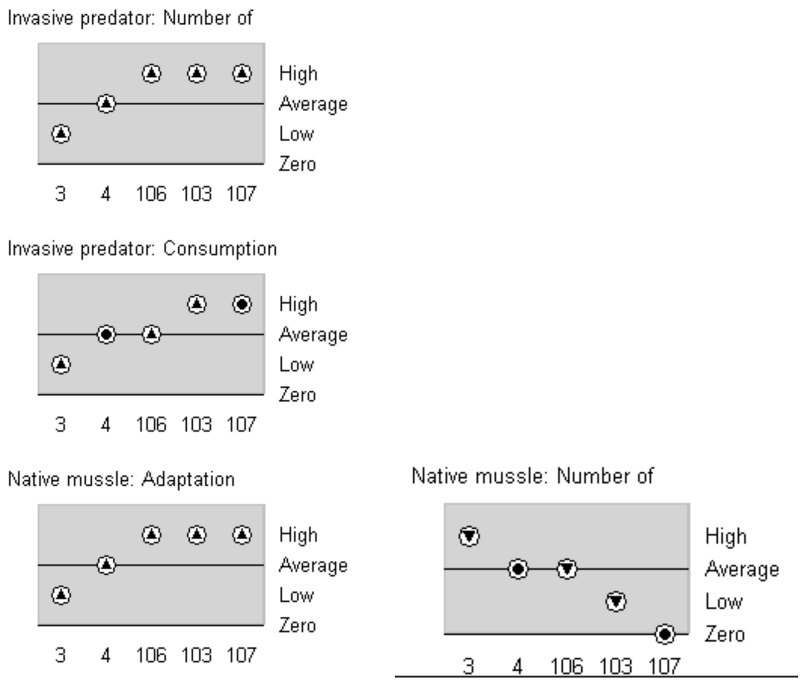
The ecosystem contains one population of each of the two species. Growth of the predator population will lead to more consumption by predation (P+). Consumption leads to a decrease in the mussel population (P-). Growth of the predator population will over time lead to adaptation of the mussel (P+). Adaptation leads to a decrease in consumption by the predator (P-).

Entity	**Quantity and Description**
Predator crab	Quantity: 1) Number of - representing the size of the crab population in the ecosystem. 2) Consumption - representing the rate at which the crabs feed on the mussel
Native Mussel	Quantity: Number of - representing the size of the mussel population in the ecosystem. Adaptation: the rate of adaptation to the invasive crab by thickening of the mussel shell.

3.1.2. Quantity space definition (LS6)

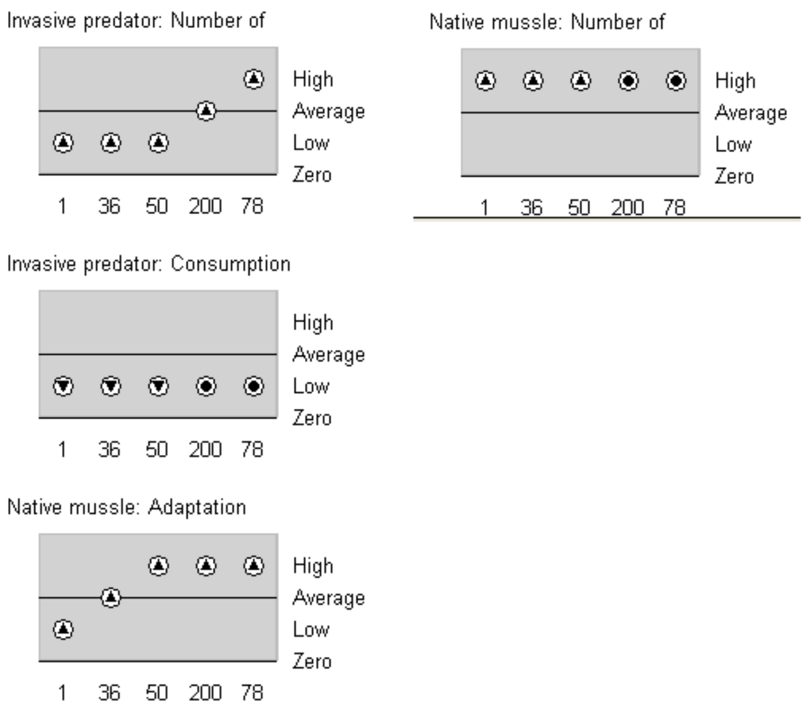
Quantity	**Quantity space**	**explanation**
Number of (crab)	Zero, Low, Average, High	Predation may lead to extinction, so Zero is present. The three others (Low, Average, High) were chosen over just Low and high in order to create longer end paths in the simulation
consumption	Zero, Low, Average, High	This quantity space was chosen to see longer dynamics of the system.
Number of (mussel)	Zero, Low, Average, High	See "Number of (crab)"
Adaptation	Zero, Low, Average, High	This quantity space was chosen to see longer dynamics of the system.

3.1.3. Scenario 01- Adaptation and predation



As the predator population increases so do the predation and the adaptation. However, the adaptation is not enough to fully stop the predation and the native mussel population decreases to extinction.

3.1.4. Scenario - Adaptation and predation



The rate of consumption decreases as the native mussel adapts to the invader. The crab population however continues to increase despite the decrease in consumption. In this path the adaptation is strong enough to stop the predation and the mussel population remains high.

3.2. Goby and Shrimp Symbiosis model

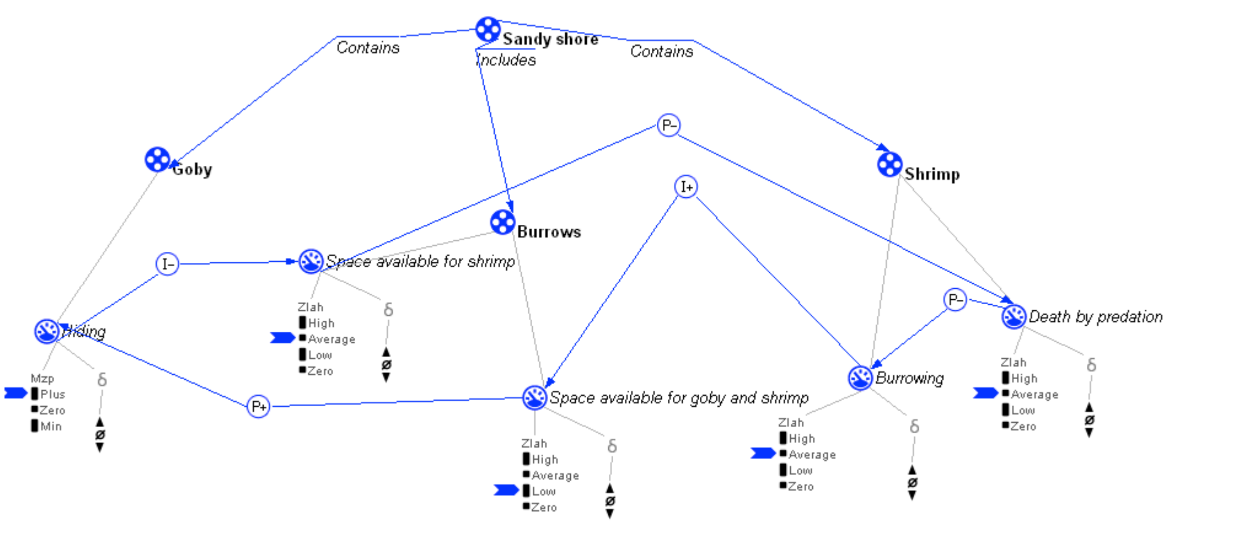
Theme / Topic	***The living world / Species interactions***		
Author	***Dror Zurel***	**Version(s)**	***DL v0.6.11(CM)***
Model	***Goby and Shrimp Symbiosis model - LS2-4***		
Target users	***Undergraduate students***		

The model is based on the article by Eschmeyer, W. N., & Herald E. S. (1983). A Field Guide to Pacific Coast Fishes of North America.

The Arrow Goby is a small estuarine fish found around sand and mud bottoms from British Columbia (Canada) to north-central Baja (Mexico). The Arrow Goby is a small, bottom-dwelling fish with its pelvic fins united to form a cuplike sucking disk. It is often found inhabiting the burrows of several invertebrate species, including the ghost shrimp, the mud shrimp and the fat innkeeper worm. In contrast to most gobies, the Arrow Goby does not build a nest or care for its young. Eggs are distributed over a considerable area, with a spawning peak from March to June. The Arrow Goby uses burrows for shelter and can be collected at low tide by digging (Eschmeyer & Herald, 1983). The Goby is believed to live commensally in the burrows of these species and uses the burrows as a refuge from predators and desiccation (drying out) at low tides. (Hoffman, 1981). Ghost shrimp and Arrow Goby were found to co-occur in burrows less frequently than they would be expected to by chance, under both field and laboratory conditions. In addition, the arrow gobies were found to inhabit the ghost shrimp burrows only during the spring and summer months.

3.2.1. Goby and Shrimp Symbiosis model LS 2-4

Structure



A hypothetical sandy shore marine ecosystem, where the shrimp burrow in the sand to hide from predators. The Goby fish use the burrows dug by the shrimps to hide from predators as well. The Goby is a parasite of the shrimp, as it competes with the shrimp for available burrow space.

Entity	Quantity and Description
Sandy shore	A hypothetical sandy shore marine ecosystem that contains burrowing shrimp and Goby fish. Has no quantity.
Shrimp	The shrimp population that burrow in the sand to escape predation. Quantities: 1) Burrowing - digging burrows. 2) Death by predation - shrimp is prayed on when no hiding space in burrows is available.
Burrow	The burrows dug by the shrimp. Quantities: 1) Space available for Goby and shrimp. 2) Space available for shrimp.
Goby	The Goby fish. Quantity: Hiding in burrows

3.2.2. Quantity space definition (LS2 - 4)

Quantity	Quantity space	explanation
Hiding	Min, Zero, Plus	The hiding rate of the Goby fish in burrows.
Space available for shrimp	Zero, Low, Average, High	Created to show how the Goby's hiding in the burrows subtracts from the space available for the shrimp. Four levels were chosen in order to create longer end paths in the simulation
Space available for Goby and shrimp	Zero, Low, Average, High	Created to show how the shrimp creates burrows that can be used by both Goby and shrimp.
Burrowing	Zero, Low, Average, High	The quantity that demonstrates the shrimp's effect on the ecosystem.
Death by predation	Zero, Low, Average, High	The quantity that demonstrates how the shrimp is affected by the Goby's parasitism.

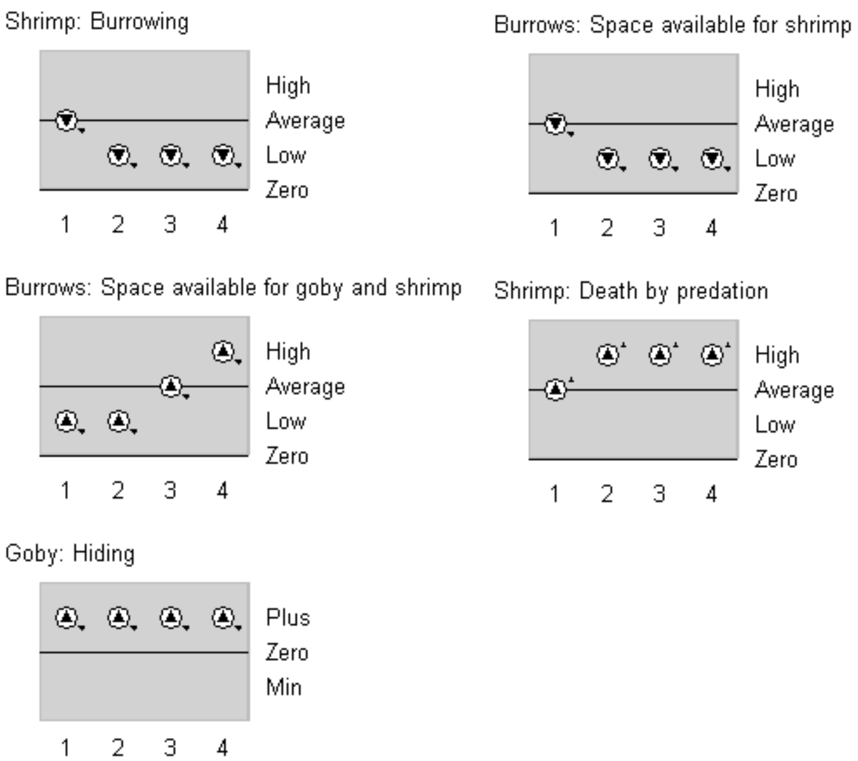
3.2.3. Scenario

LS2 demonstrates the nature of the parasitism/competition between the Goby fish and the shrimp over space in the burrows. LS3 - 4 further complicate the model by showing how the Shrimp is affected by this competition, as it is being prayed on if it can't hide in the burrows.

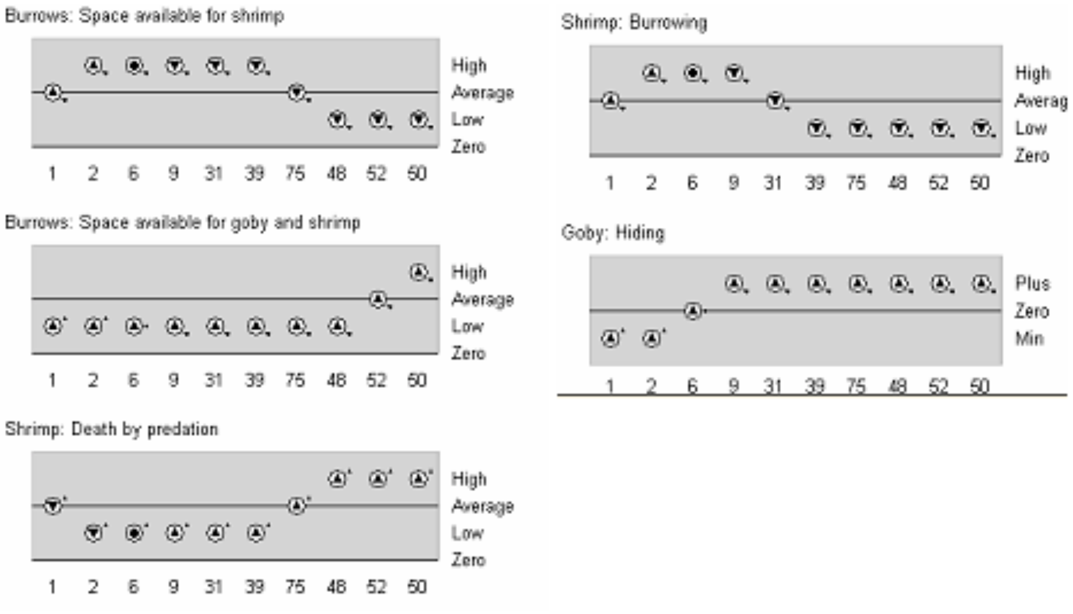
LS6 demonstrates the nature of the symbiosis, as both Goby and shrimp are affected by the symbiosis. By changing the population size of each member and observing the effect this change has on the other member the student can define what kind of relationship the two members have, mutualism, parasitism or competition.

LS2 - 6 models all show that the Goby has a negative effect on the shrimp population due to competition.

The following end-state is observed in the LS4 model:



Shrimp burrowing decreases as more shrimp die of predation, however as long as there are shrimp there is burrowing, therefore space available for hiding increases. The Goby hides in the burrows and out-competes the shrimp, leading to their death by predation. When the Goby hiding rate is place as negative, several end states are observed, all giving similar final results.



At first the Shrimp population is growing and more burrows are being dug. This leads to more hiding by Goby shrimp, which leads to more predation of the shrimp, and then to less burrowing by the shrimp.

3.3. Competition for space

Theme / Topic	*The living world / community specific features*		
Author	*Dror Zurel, Moshe Leiba, Anat Milgrom*	***Version(s)***	*DL v0.6.11(CM)*
Model	*Competition for space - LS2, LS6*		
Target users	*Undergraduate students*		

This model is based on the findings of the following article:

Rius, M., and McQuaid, C. (2009). Facilitation and competition between invasive and indigenous mussels over a gradient of physical stress. *Basic and Applied Ecology, 10*, 607-613.

An invasive species is a species living outside its native distributional range, which has arrived to its new location by human activity, either deliberate or accidental. Introduced species have vast effects on the native flora and fauna, and they often out-compete the native species for resources such as food, nutrients and settlement grounds. The interactions between invasive c and indigenous species can have profound harmful effects on the recipient community; however, not all such interactions are negative. The invasive species may also change its surrounding environment in a way that promotes a certain indigenous species and may even facilitate its growth. Some indigenous species, like the mussel described in the article, may also facilitate the success of the invader.

The article on which the model is based shows that the indigenous South African intertidal mussel Perna perna initially facilitates survival of the invasive Mediterranean Mytilus galloprovincialis in the low mussel zone of the Eastern Mediterranean Sea by providing protection against waves. However, it later excludes M. galloprovincialis through interference and competition for space.

The model contains two population entities, the indigenous South African intertidal mussel Perna perna and of the invasive Mediterranean Mytilus galloprovincialis.

There are two main model fragments in the model:

1) Facilitation: the invasive mussel facilitates the survival of young native mussels by protecting them from the waves.

2) Competition: the two mussel species compete with each other for settling space on the rocky shore.

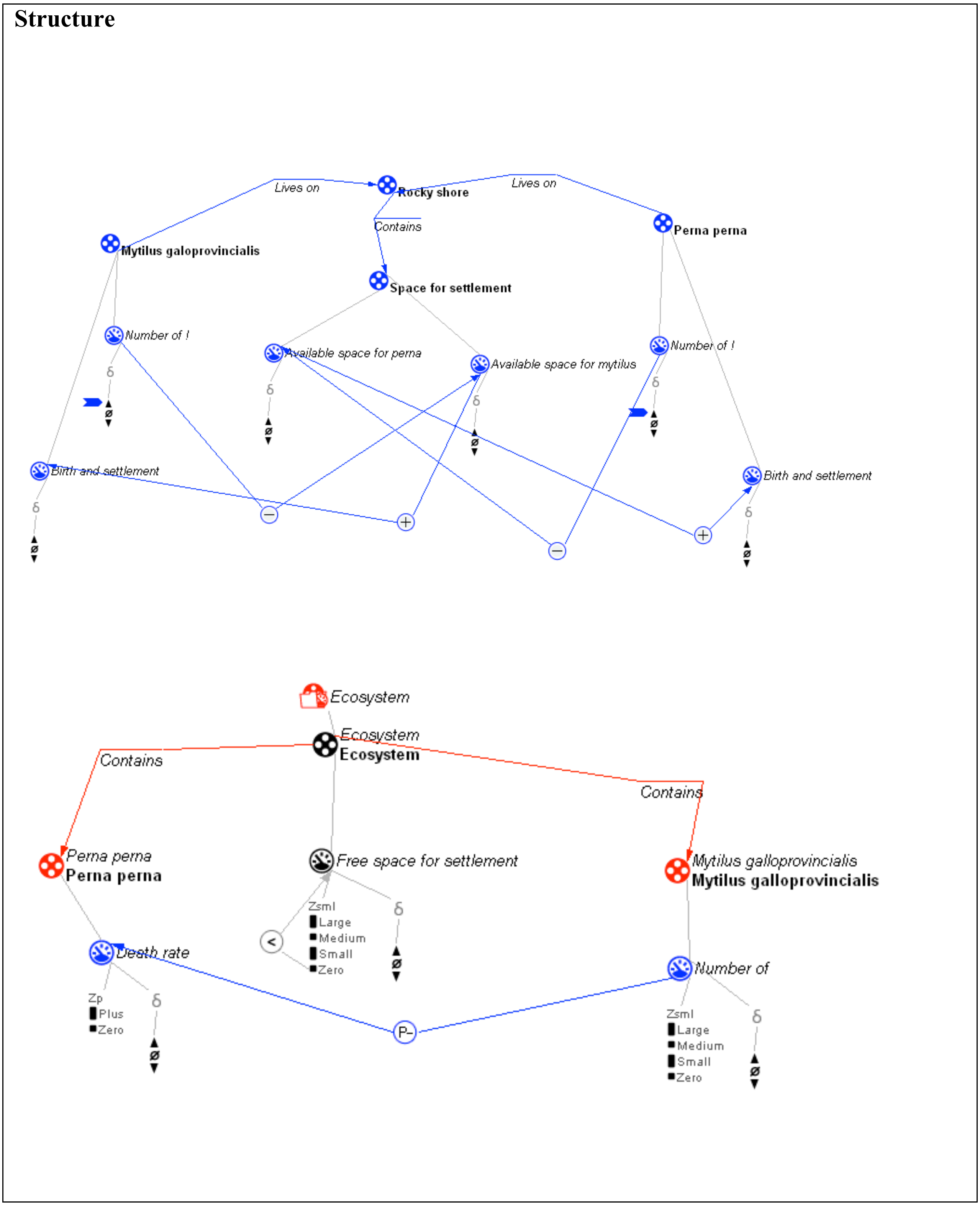
The model has two scenarios:

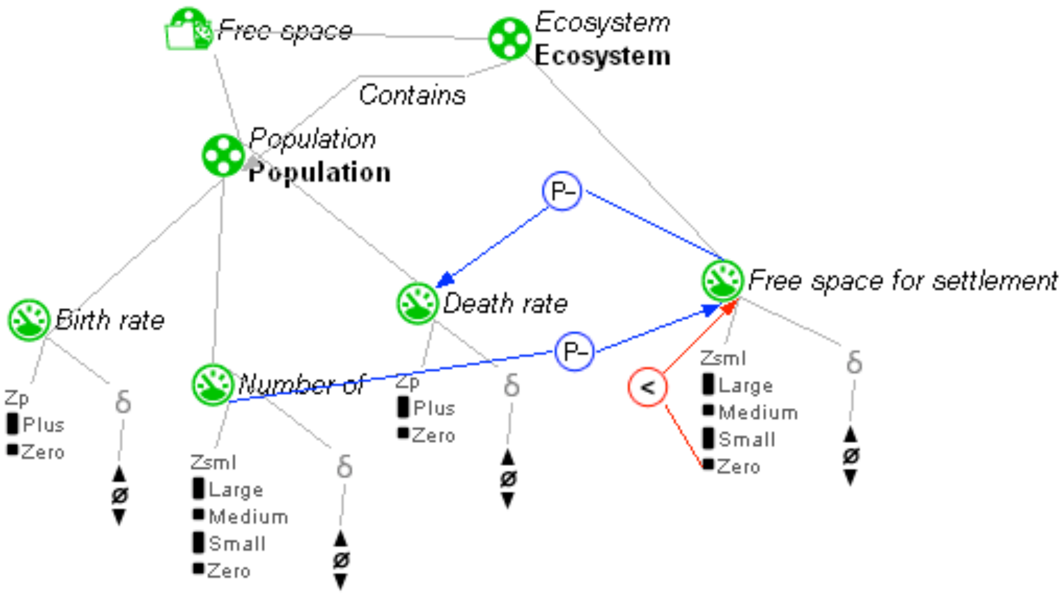
1) Before invasion. The only quantities present are the number of Perna perna mussels and the amount of space available for settlement.

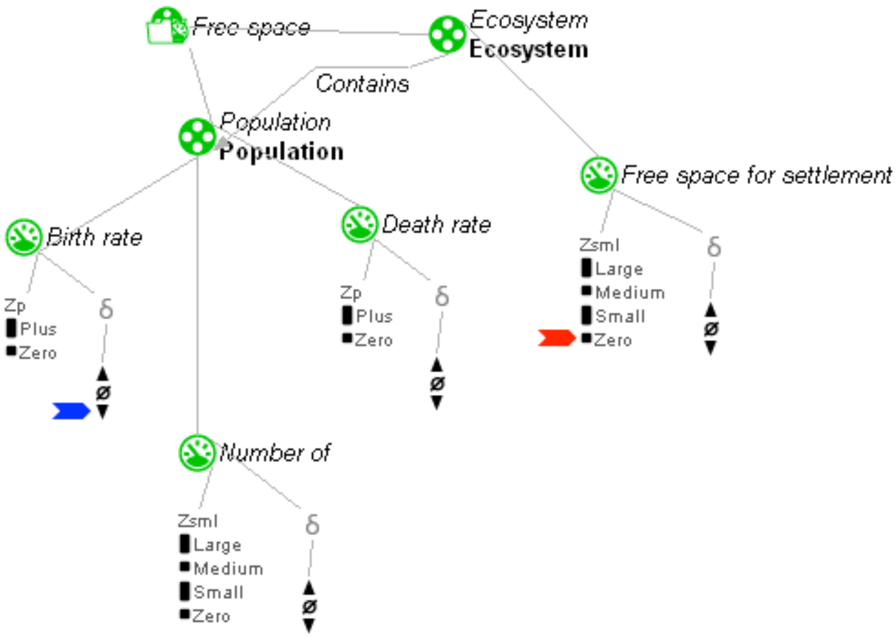
2) After invasion: Both invasive and native mussels exist in this scenario.

The effect of the invasive species on the native one is shown when comparing the results of the two scenarios.

3.3.1. Competition for space LS 2, 6







Mytilus galloprovincialis facilitates the survival of Perna perna by protecting them from the waves. This is an indirect effect, thus is presented as a P-.

If the amount of free space for settlement is larger that 0, than two consequences exist:

1) A rise in the number of individuals of a population leads to less free space (P-).

2) Free space allows settlement and thus survival of a population, thus indirectly affecting the population death rate (P-).

If the amount of free space equals 0, than as a consequence the population Birth rate drops as larva have no place to settle. Birth rate also represents initial survival of the larvae.

Entity	Quantity and Description
Marine ecosystem	A hypothetical marine ecosystem that contains fish and algae and that is being exploited by the fishing industry. Quantity: Free space for settlement
Population	Both populations. Quantities: Birth rate, death rate, number of.

3.3.2. Quantity space definition (LS2, 6)

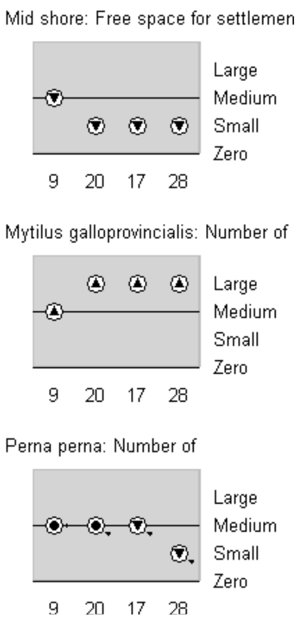
Quantity	Quantity space	explanation
Birth rate	Zero, Plus	The reproduction rate of the population
Death rate	Zero, Plus	The mortality rate of the population
Number of	Zero, small, medium, large	The number of individuals in a population
Free space for settlement	Zero, small, medium, large	Space on the rocky shore that is suitable and available for mussel larva to settle on and attach to

3.3.3. Scenario

After invasion, both invasive Mytilus galloprovincialis and native Perna perna exist in the Mid shore ecosystem, thus competing for free settlement space.

In this scenario we assume Mytilus is not a successful invader (as set by the primary conditions death>birth). As the Mytilus population decreases the population of Perna perna mussel's increases and the amount of free space available for settlement decreases due to settlement of new mussel larva.

The following end-state is observed in the LS6 model:



As the Mytilus population increases there is less free space for settlement, and the Perna Perna population decreases.

3.4.

3.4 Metabolism and Acidity

Theme / Topic	***Global changes / Adaptation to climate change in marine ecosystems***		
Author	***Dror Zurel, Moshe Leiba***	***Version(s)***	***DL v0.6.11(CM)***
Model	***Metabolism and Acidity - LS2-6***		
Target users	***Undergraduate students***		

This model is based on the following article:

1. Ellis R., Bersey J., Rundle S., Hall-Spencer J., and Spicer, J. (2009). Subtle but significant effects of CO2 acidified seawater on embryos of the intertidal snail, Littorina obtusata. *Aquatic Biology, 5*(1):41-48.

The ongoing decrease in the pH of the Earth's oceans, caused by their uptake of anthropogenic carbon dioxide from the atmosphere, is leading to ocean acidification.

Ocean acidification has great effect on marine life, some of which have Calcium-based skeletons that may degrade at low pH. The article on which this model is based disribes the effect low pH has on the development of marine snails.

Larval and adult heart rates were significantly lower in acidified seawater.

Under low oxygen stress, increasing the heart rate allows transportation of sufficient oxygen into the body cells. Lower heart rates in an acidic environment may further disable the snail's ability to survive low oxygen stress.

The model contains a seawater environment and a Littorina larva that lives within it. The model demonstrates the effects of low oxygen stress on the larva under neutral or acidic conditions.

There are two main model fragments in the model:

1) MF02a Low oxygen: The oxygen concentration in the sea water affects that of the larva's. When sea water oxygen levels are low, the larva oxygen concentration drops. When that happens the lava's heart rate increases in order to increase the blood circulation and cause more oxygen to diffuse into the blood and be transported to the body cells.

2) MF02b Acidic pH: under acidic pH conditions the heart rate is low and remains low, regardless of oxygen levels.

The model has two scenarios:

"Sce01 Metabolism under low oxygen levels"

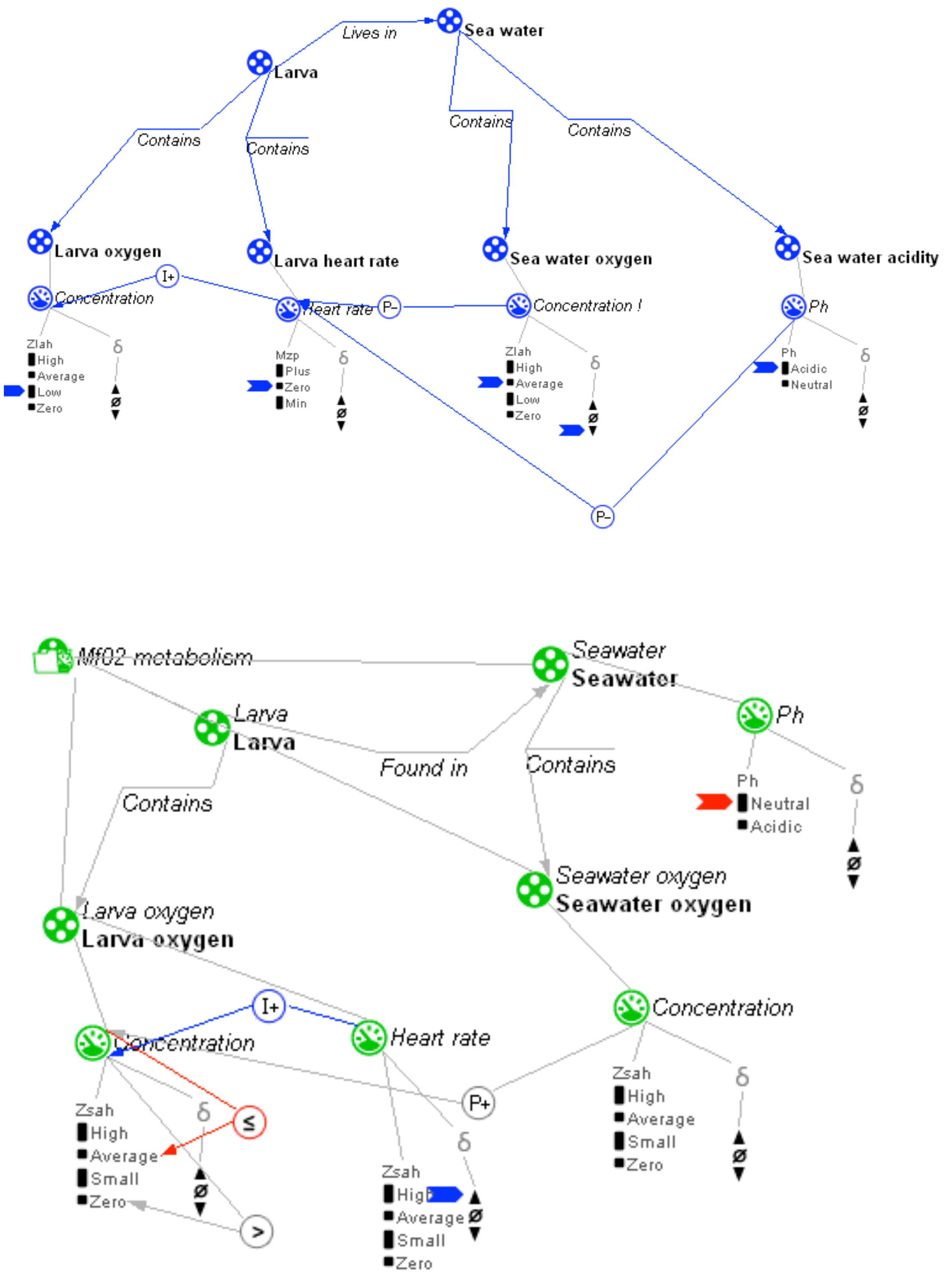
In this scenario the pH is neutral and the model user can see how different sea water oxygen levels affect those of the larva and its heart rate.

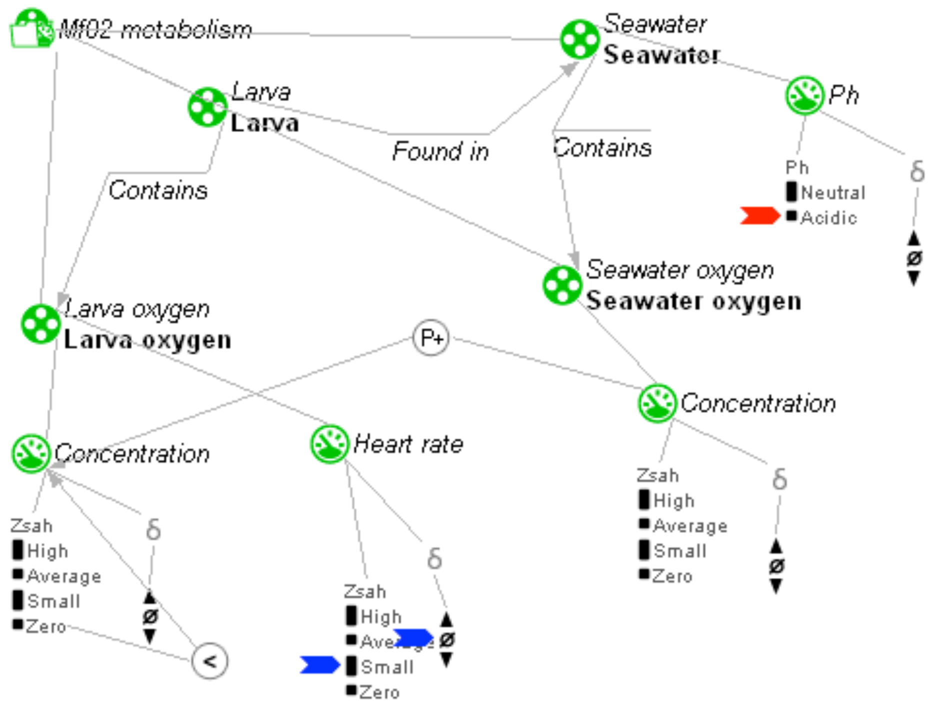
"Sce02 Metabolism in acidic sea water"

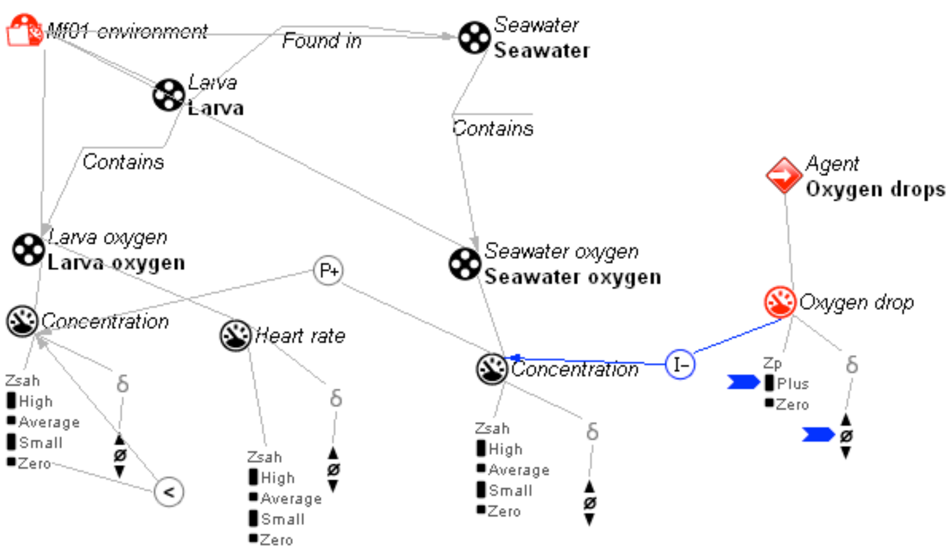
In this scenario the pH is acidic. The heart rate remains low and sea water oxygen levels have no affect.

3.4.1. Metabolism and acidity LS 2-6

Structure







The oxygen concentration in the sea water affects that of the larva's. When sea water oxygen levels are low, the larva oxygen concentration drops. When that happens the lava's heart rate increases in order to increase the blood circulation and cause more oxygen to diffuse into the blood and be transported to the body cells. This has a direct I+ influence on the larva's oxygen levels.

Under acidic pH conditions (condition) the heart rate is low and remains low, regardless of oxygen levels (consequence).

The oxygen depletion agent causes a constant decrease in sea water oxygen. This is a low oxygen stress that causes larval oxygen levels to decrease as well.

Entity	Quantity and Description
Sea water	Quantities: Oxygen concentration PH
Larva	Quantities: Heart rate Oxygen concentration

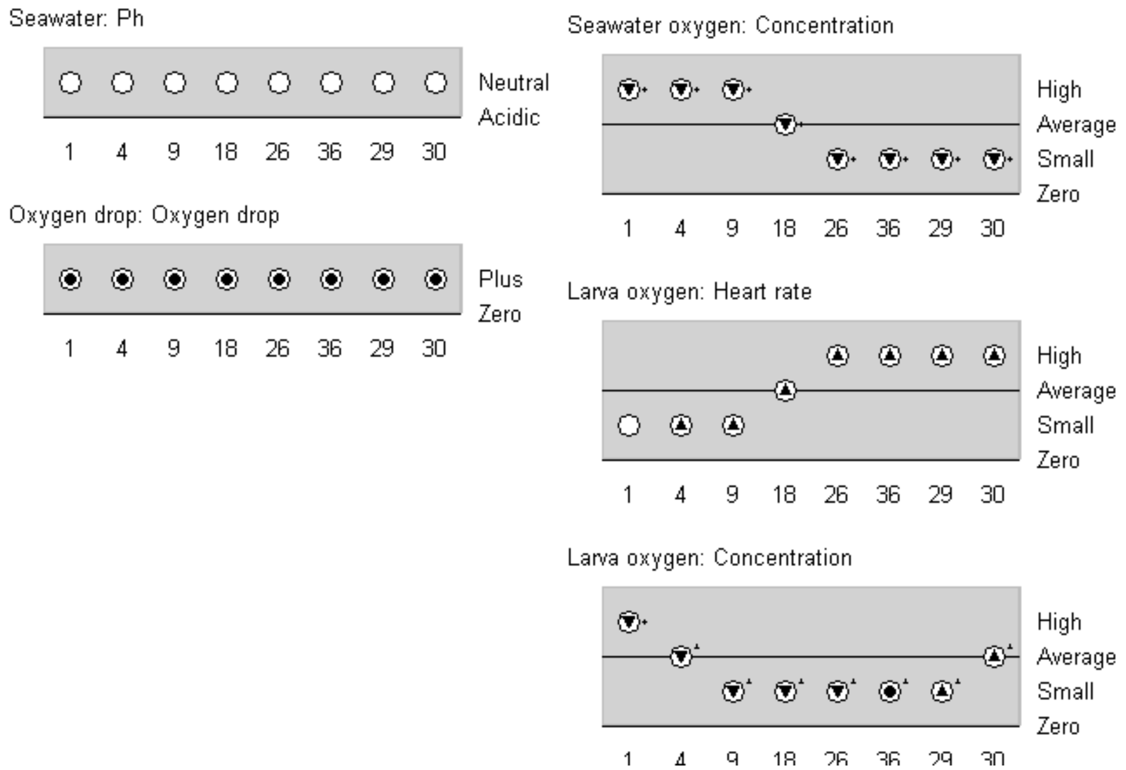
3.4.2. Quantity space definition (LS2, 6)

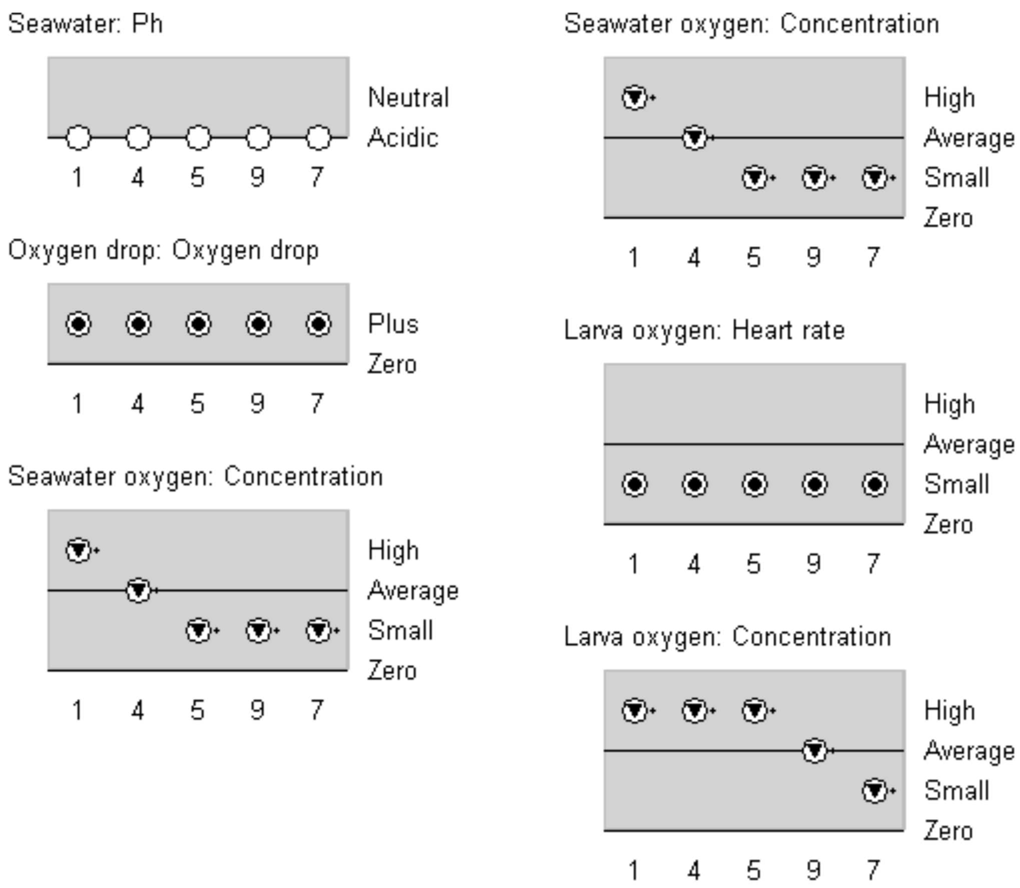
Quantity	Quantity space	Remarks
Oxygen concentration	Zero, small, average, high	Oxygen concentration in the sea water
pH	PH (acidic, neutral)	pH levels
Oxygen concentration	Zero, small, average, high	Oxygen concentration in the larva's blood and tiddues
Heart rate	In LS 6 Zero, small, average, high In LS2-4 Minimum, zero, plus	Heart rate of the larva

3.4.3. Scenario - Metabolism under low oxygen levels

In this scenario the pH is neutral and the model user can see how different sea water oxygen levels affect those of the larva and its heart rate. When PH is acidic the heart rate is not effected by the oxygen concentration in the sea water.

The following end-state is observed in the LS6 model:


Seawater: Ph
Neutral
Acidic
1 4 9 18 26 36 29 30
Oxygen drop: Oxygen drop
Plus
Zero
1 4 9 18 26 36 29 30
Seawater oxygen: Concentration
High
Average
Small
Zero
1 4 9 18 26 36 29 30
Larva oxygen: Heart rate
High
Average
Small
Zero
1 4 9 18 26 36 29 30
Larva oxygen: Concentration
High
Average
Small
Zero
1 4 9 18 26 36 29 30


Seawater: Ph
Neutral
Acidic
1 4 5 9 7
Oxygen drop: Oxygen drop
Plus
Zero
1 4 5 9 7
Seawater oxygen: Concentration
High
Average
Small
Zero
1 4 5 9 7
Seawater oxygen: Concentration
High
Average
Small
Zero
1 4 5 9 7
Larva oxygen: Heart rate
High
Average
Small
Zero
1 4 5 9 7
Larva oxygen: Concentration
High
Average
Small
Zero
1 4 5 9 7

3.5. TBT and Imposex models

Theme / Topic	***Pollution / The chemistry and physics of marine environments***		
Author	***Dror Zurel, Moshe Leiba, Moran Richental, Ella Shtibelman***	***Version(s)***	***DL v0.6.11(CM)***
Model	***TBT and Imposex models - LS2-4, LS6***		
Target users	***Undergraduate students***		

This model is based on the following article:

Chiavarini, S., Massanisso, P., Nicolai, P., Nobili, C., and Morabito, R. (2003). Butyltins concentration levels and imposex occurrence in snails from the Sicilian coasts (Italy). *Chemosphere, 50*, 311-319

Biofouling is the undesirable accumulation of micro-organisms, algae and diatoms, plants, and animals on surfaces, for example ships' hulls, or piping and reservoirs with untreated water. This accumulation may cause corrosion and slow down ships, leading to higher fuel consumption. To prevent this, boats and ships use Antifouling paint that discourages the growth of barnacles, weed, and other water life on the submersed hull. However, these paints contain a substance called Tributyltin (TBT) that is toxic to marine invertebrates.

Tributyltin (TBT) from maritime traffic is highly toxic towards non-target organisms, and has a high tendency to be accumulated in marine organisms. Decline of gastropod populations has been registered worldwide as a consequence of the induction of the imposex effect by TBT, consisting in a superimposition of male sexual characteristics on female organisms. The following model shows the effect of TBT from marine traffic on a gastropod population, as imposex caused by TBT leads to a decrease in the number of fertile females, and therefore restrains the population growth.

The model contains a population of the marine snail Hexaplex trunculus as the main entity and ships with TBT-based antifouling paint as the polluting agent. The TBT aggregates in the sediment entity and is measures as a "TBT concentration" quantity.

There are two main model fragments in the model:

1) Imposex: TBT concentration has an indirect negative effect on the number of fertile Hexaplex trunculus females in the population. The number of fertile females has an indirect positive effect on the population birth rate, as unfertile females can not reproduce.

2) The ships agent: When ships with TBT paint are present the TBT concentration in the sediment rises. When ships are no longer present the TBT does nor immediately disappear from the sediment, but is slowly degraded.

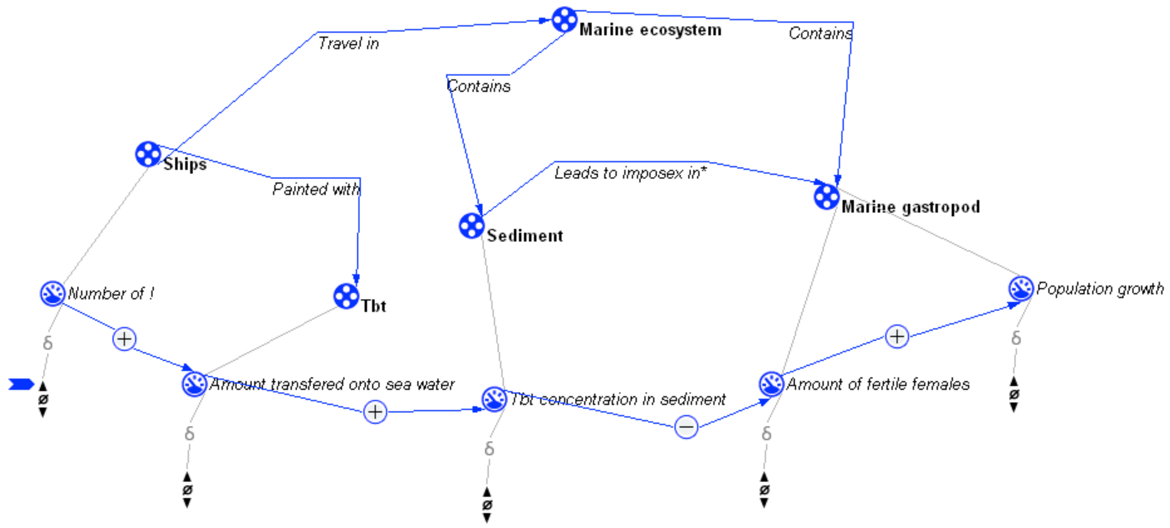
The model has one scenario:

"Population dynamics under the influence of TBT"

The Mediterranean Sea ecosystem contains the Hexaplex trunculus population and the sediment where TBT from passing ships is aggregated. The ships agent is either on plus (ships present) of zero (no ships or ships without TBT paint).

3.5.1. TBT and imposex LS 2-4

Structure

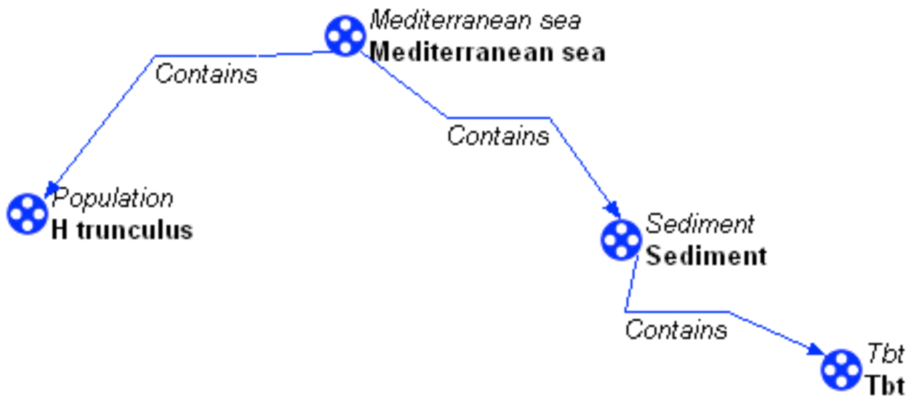


A hypothetical marine ecosystem that contains a gastropod population. The gastropod population growth depends on the amount of fertile females that can reproduce. TBT antifouling paint from ships accumulates in the sediment and leads to imposex, a phenomenon that reduces the amount of fertile females in the gastropod population.

Entity	**Quantity and Description**
Marine ecosystem	A hypothetical marine ecosystem that contains sediment and a gastropod population. Has no quantity.
Ships	Ships that travel in the marine ecosystem and are painted with TBT paints. Quantity: number of - The amount of ships that are present in the ecosystem at a given time.
TBT	Antifouling paint that is transferred from ships to the seawater and accumulates in the sediment. Quantity: 1) Amount transferred onto sea water.
Sediment	The sediment in the ecosystem's sandy bottom. Quantity: TBT concentration in sediment.
Marine gastropod	The marine gastropod population that is affected by the TBT pollution. Quantities: 1) Population growth rate. 2) Number of fertile females - the quantity that is affected directly by TBT.

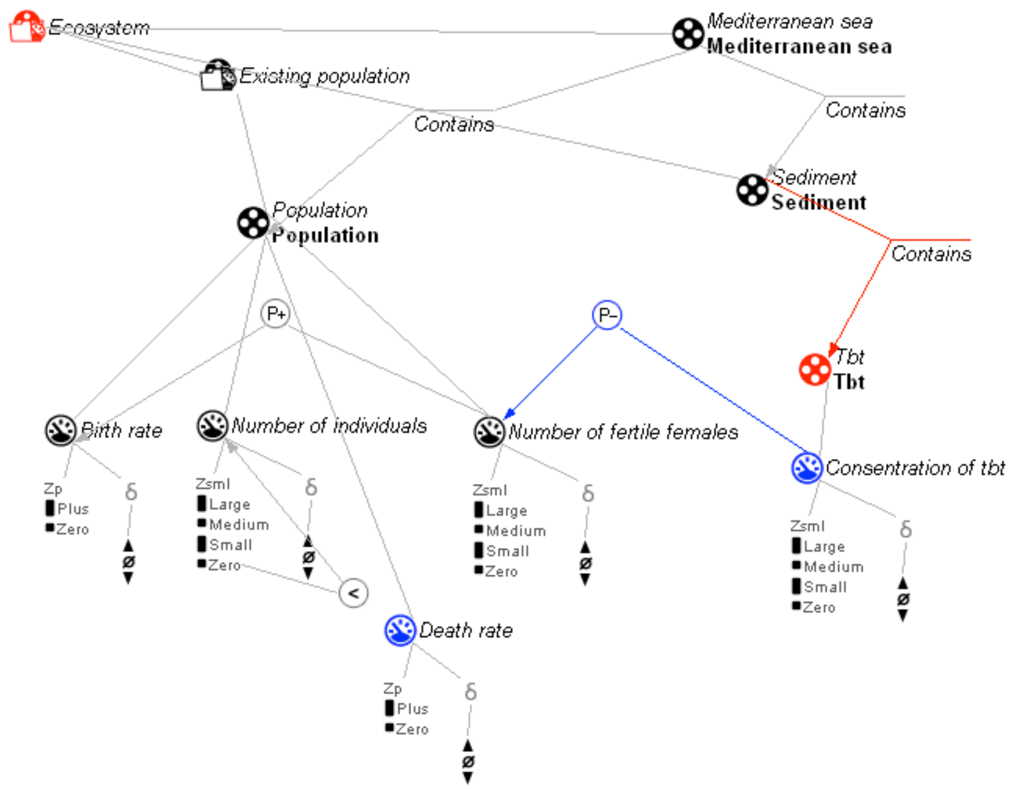
3.5.2. TBT and imposex LS6

Structure

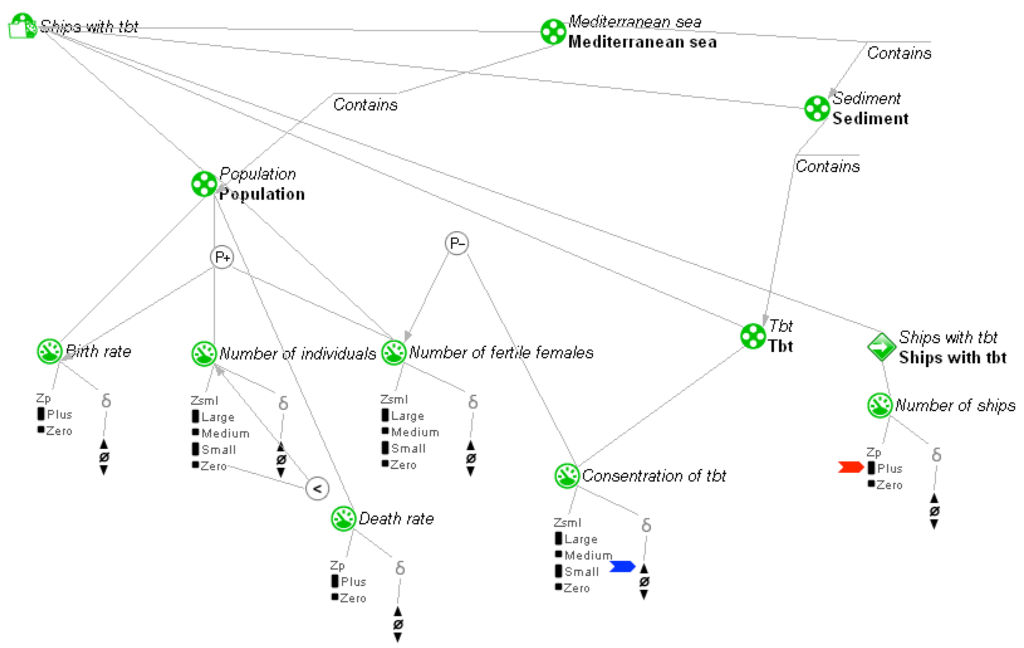


A hypothetical marine ecosystem that contains a gastropod population. The gastropod population growth depends on the amount of fertile females that can reproduce. TBT antifouling paint from ships accumulates in the sediment and leads to imposex, a phenomenon that reduces the amount of fertile females in the gastropod population.

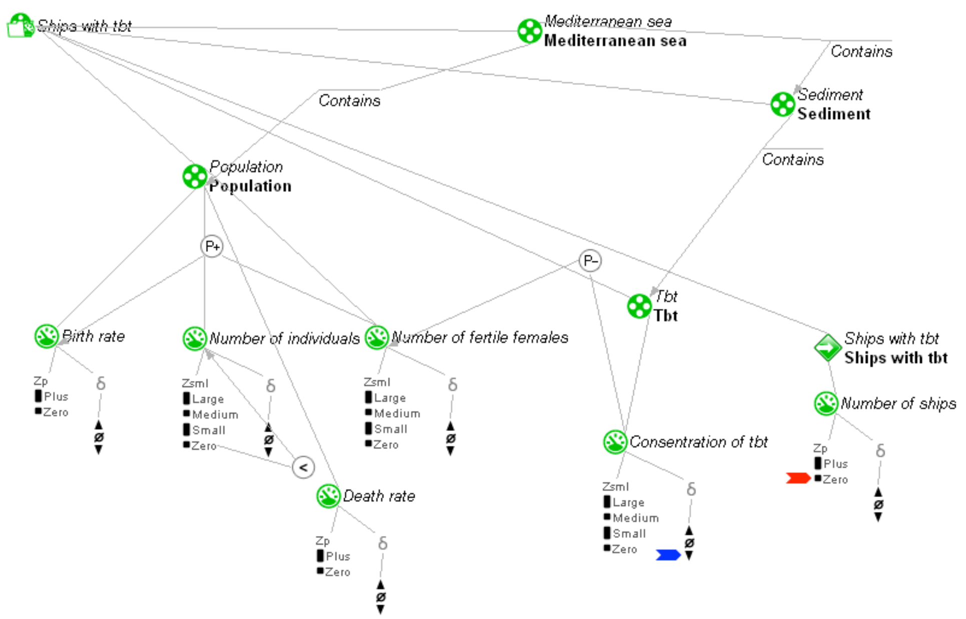
MF1



MF2



MF3



If the sediment contains TBT (condition) than the concentration of TBT has a P- effect on the number of fertile Hexaplex trunculus females, which have a P+ effect on the population's birth rate.

If the Ships agent is on plus (condition) than as a consequence the concentration of TBT in the sediment increases.

If ships using TBT paints stop sailing in the ecosystem (condition) than as a consequence the TBT concentration in the sediment will begin to decrease.

Entity	Quantity and Description
Marine ecosystem	A hypothetical marine ecosystem that contains sediment and a gastropod population. Has no quantity.
Ships	Ships that travel in the marine ecosystem and are painted with TBT paints. Quantity: number of - The amount of ships that are present in the ecosystem at a given time.
TBT	Antifouling paint that is transferred from ships to the seawater and accumulates in the sediment. Quantity: 1) Amount transferred onto sea water.
Sediment	The sediment in the ecosystem's sandy bottom. Quantity: TBT concentration in sediment.
Marine gastropod	The marine gastropod population that is affected by the TBT pollution. Quantities: 1) Population growth rate 2) Number of fertile females - the quantity that is affected directly by TBT.

3.5.3. Quantity space definition (LS 3-6)

Quantity	Quantity space	explanation
Number of Ships	Zero, Low, Average, High	Ships may stop travelling in the ecosystem or be replaced by non-TBT ships, so Zero is present. The three others (Low, Average, High) were chosen over just Low and high in order to create longer end paths in the simulation
Number of fertile females	Zero, Low, Average, High	Imposex may lead to zero fertile females, so Zero is present. The three others (Low, Average, High) were chosen over just Low and high in order to create longer end paths in the simulation
TBT amount transferred to the sea water and concentration in sediment	Zero, Low, Average, High	chosen in order to create longer end paths in the simulation

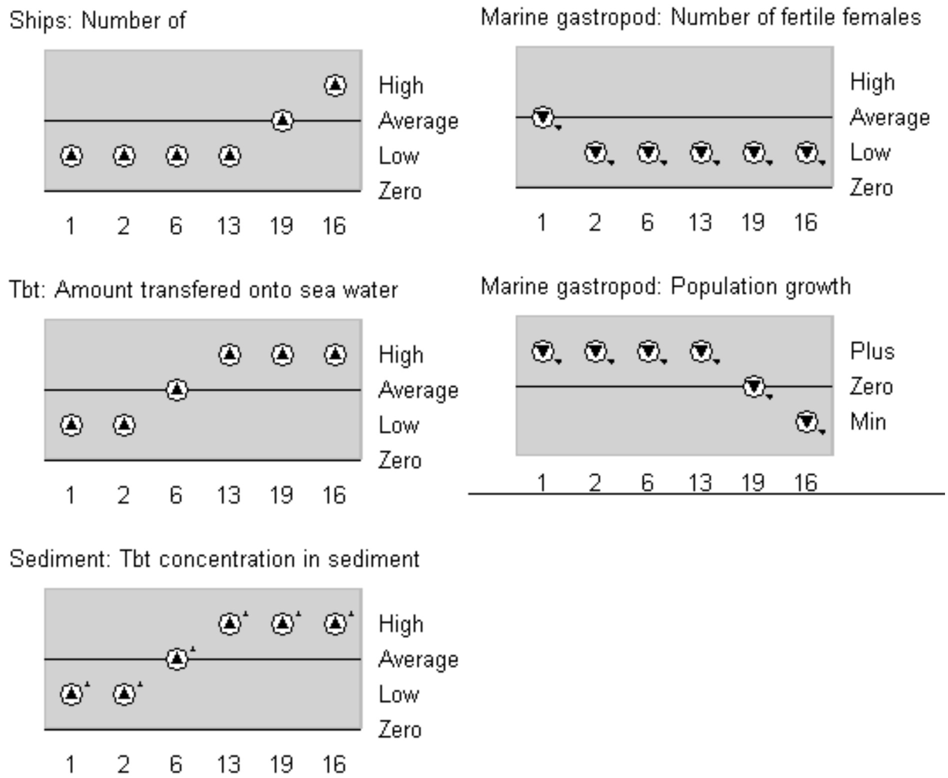
Population growth	Min, Zero, Plus	Growth rate may be positive, zero or negative.

3.5.4. Scenario

LS2 - 4 demonstrate the effect TBT has on the marine gastropod population in a simplified way, where all the processes that naturally affect the population size are summed into one quantity, population growth rate. LS6 has a more complex system in which birth and death dynamics affect the population size. LS 2-4 allow a simpler understanding of the effects of TBT, while LS6 demonstrate this effect on a model that better represents real life.

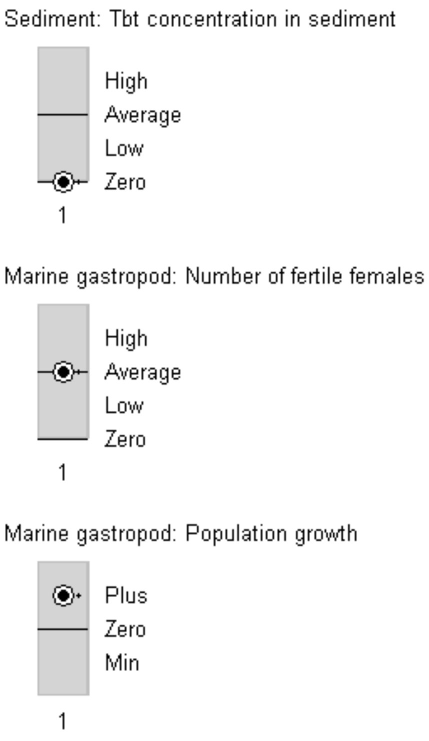
LS2 - 6 models all show that TBT concentrations in the sediment lead to decrease in the number of fertile females and lead to a negative growth rate. Even if the ships are no longer in the system, even low TBT concentrations left in the sediment lead to imposex and a decrease in fertile females. The student has to completely eliminate all TBT from the scenario in order to see positive growth rate, because just eliminating the ships is not enough.

The following end-state is observed in the LS4 model when TBT is present:



TBT concentration increase leads to decrease in fertile gastropod females, leading to negative growth rates.

The following end-state is observed in the LS4 model when TBT is absent:



When TBT is not present the population growth is positive. LS6 model shows similar results.

The model shows the effect of pollution on living creatures. This effect is not a direct one, so this model demonstrates how pollution affects nature in the long run. Additionally, the model demonstrates that present actions have future implications. Even if we stop pollution now the pollution and its effects will not fully disappear right away but only after a certain period of time. Therefore the sooner we stop polluting the sooner the ecosystem may recover.

3.6. Diving pressure

Theme / Topic	***Human population / Biotechnological exploitation of marine organisms***		
Author	***Dror Zurel***	***Version(s)***	***DL v0.6.11(CM)***
Model	***Diving pressure - LS3***		
Target users	***Undergraduate students***		

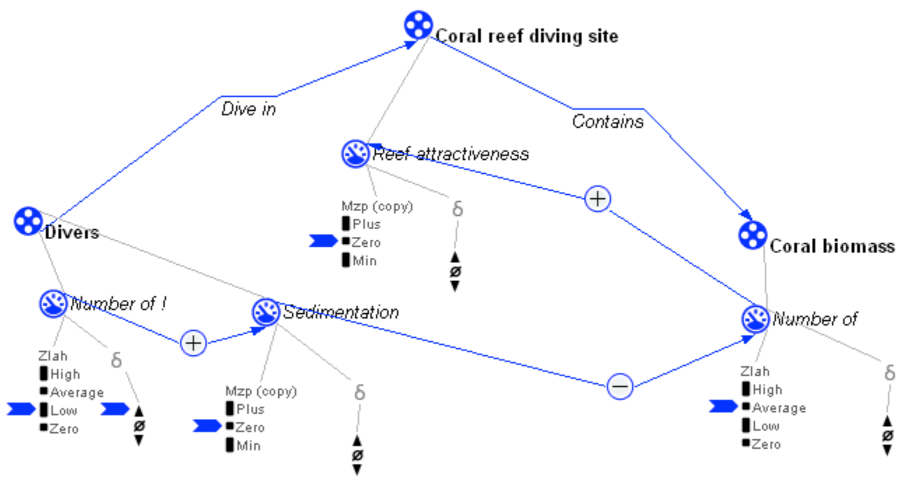
This model is based on the following article:

Hasler, M., and Ott, J. (2008). Diving down the reefs? Intensive diving tourism threatens the reefs of the northern Red Sea. *Marine Pollution Bulletin, 56*, 1788–1794.

Dahab (Egypt) coral reefs are under extreme diving pressures of over 30,000 dives a year. The tourism sector has a very powerful lobby in Egypt and is growing fast. Divers cause massive damage to corals (Hassler & Ott, 2008). Sedimentation happens mostly when divers enter the site. New divers, who haven't mastered their buoyancy, cause the most damage. In the model, the effect of "reef attractiveness" (decreasing as a function of damage to Corals) on diving activity is explored.

3.6.1. Diving pressure LS3

Structure



Divers cause sedimentaton that kills corals, leading to a decrease in coral biomass. A decrease in the biomass makes the reef less attractive for future divers.

Entity	**Quantity and Description**
Divers	Number of Sedimentation
Coral reef diving site	Reef attractiveness
Coral biomass	Number of

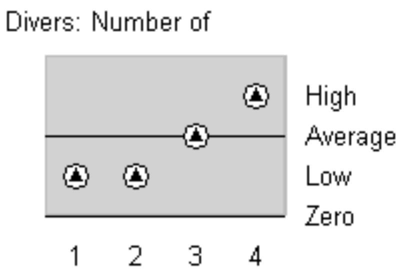
3.6.2. Quantity space definition (LS3)

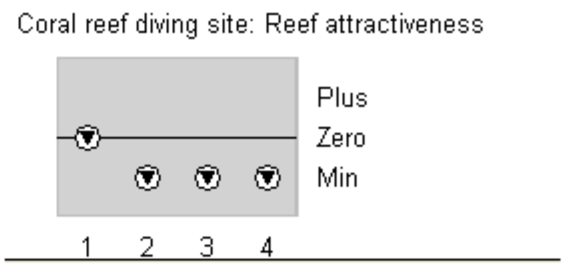
Quantity	**Quantity space**	**Remarks**
Number of	Zero, low, average, high	Number of corals and divers
Reef attractiveness	Minus, zero, plus	May be positive or negative
sedimentation	Minus, zero, plus	May be positive or negative

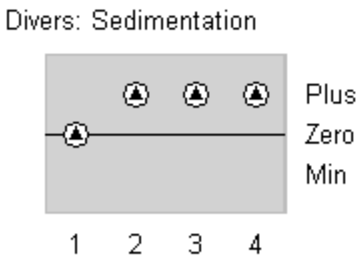
3.6.3. Scenario - Diving pressure on a coral reef

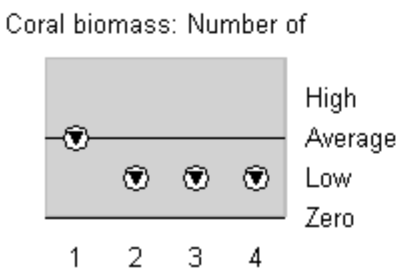
In this scenario Divers cause sedimentaton that kills corals, leading to a decrease in coral biomass. A decrease in the biomass makes the reef less attractive for future divers.

The following end-state is observed in the LS3 model:









The "reef attractiveness" quantity should have a + effect on "number of divers", and the number of divers should decrease due to coral death, but this does not work in LS3. P and I in LS4 may help solve this problem.

3.7. Over fishing model

Theme / Topic	Human population / Biotechnological exploitation of marine organisms		
Author	Dror Zurel, Moshe Leiba	Version(s)	DL v0.6.11(CM)
Model	Over fishing model - LS2-4, LS6		
Target users	Undergraduate students		

Over three quarters of our planet are covered by the oceans. Their biodiversity is unmatched and they contain over 80 percent of all life on earth, mostly unexplored. Millions of people worldwide are depending on the oceans for their daily livelihoods. Over fishing occurs when fishing activities reduce fish stocks below an acceptable level, under which fish populations may not be able to recover. Ultimately over fishing may lead to extinction of fish.

Damaging the fish population may have a chain effect on the rest of the ecosystem. The following model shows such a scenario, in which over fishing leads to a decrease in grazer fish, which In turn leads to an increase in the algae population. In a natural ecosystem, the grazer-algae populations remain in equilibrium, as consumption depends on supply and vice versa. However, over fishing breaks this equilibrium, leading to less consumption. This effect may be positive for the algae population; however other marine species, such as corals that compete with algae for settlement space on the reef, may be out-competed.

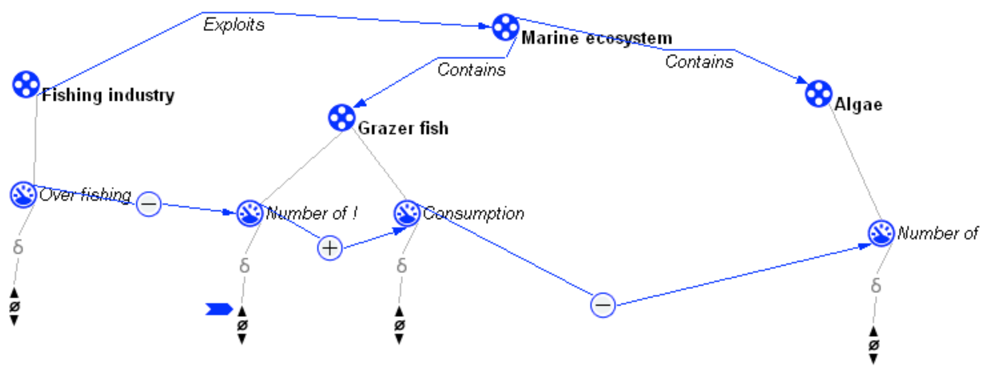
The model contains two population entities, the indigenous grazing fish and the grazed-on algae. There is also an agent, the fishing industry that is over-fishing the ecosystem.

There is one main model fragment in the model: MF01 Grazing. This fragment describes the interactions between the grazer population and the algae population.

The model has one scenario: Grazing with algae and grazer. The scenario includes the Algae population, the grazing fish population and the over-fishing agent.

3.7.1. Over fishing LS 2-4

Structure

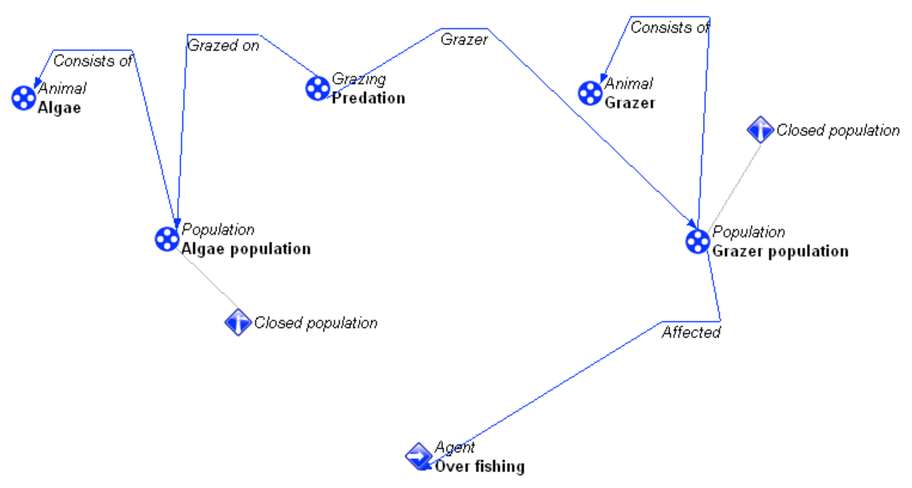


A hypothetical marine ecosystem, where fish graze on algae, is disturbed by the local fishing industry. Over fishing leads to a decrease in the amount of fish, thus leading to a decrease in the amount of algae, as less grazing by fish is happening. The model assumes that there are only grazer fish and the alga they graze on in the ecosystem. The fish population grows at first, until decreased by over fishing.

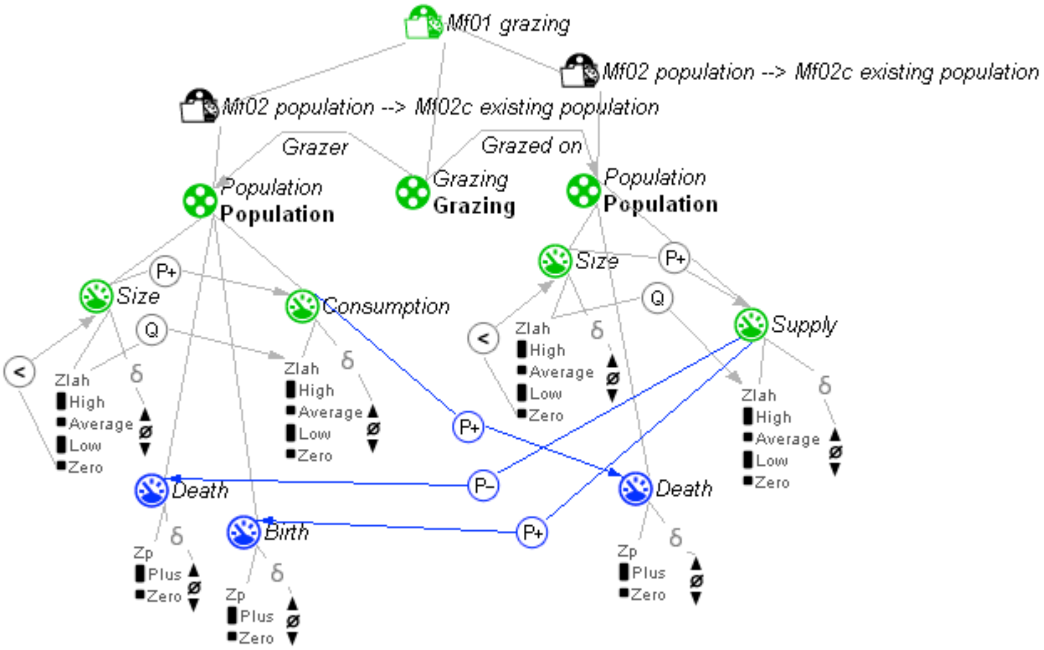
Entity	**Quantity and Description**
Marine ecosystem	A hypothetical marine ecosystem that contains fish and algae and that is being exploited by the fishing industry. Has no quantity.
Fishing industry	Any kind of fishing activity that exploits the fish population of the marine ecosystem. Quantity: Over fishing - this quantity means that more fish are being fished than being born; therefore it has a negative effect on the fish population size.
Grazing fish	Fish that feed on algae. Quantity: 1) Number of - representing the size of the fish population in the ecosystem. 2) Consumption - representing the rate at which the fish feed on the algae
Algae	Algae grazed by the fish. Quantity: Number of - representing the size of the algae population in the ecosystem.

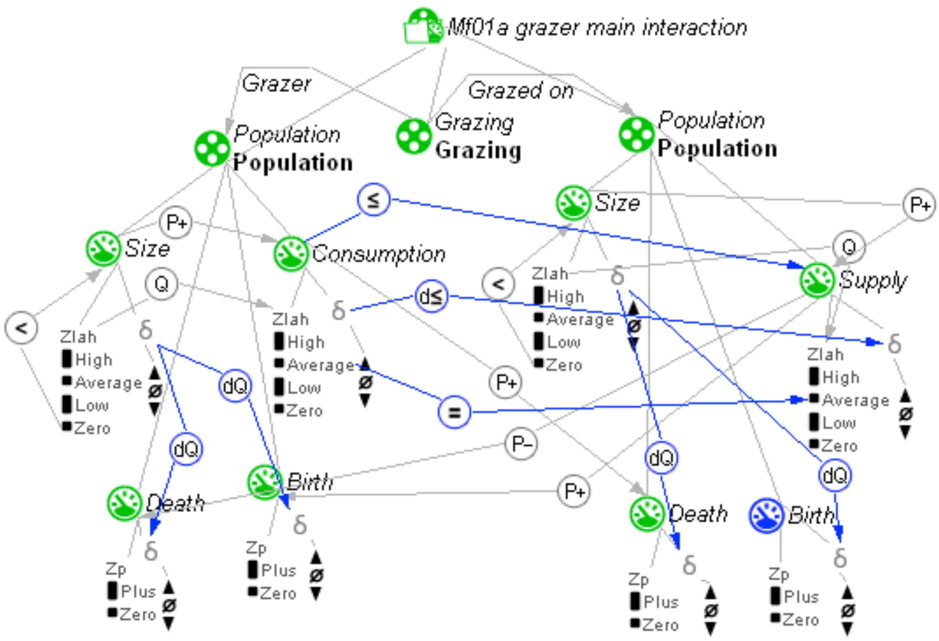
3.7.2. Over fishing LS6

Structure



A hypothetical marine ecosystem, where fish graze on algae, is disturbed by the local fishing industry. Over fishing leads to a decrease in the amount of fish, thus leading to a decrease in the amount of algae, as less grazing by fish is happening. The model assumes that there are only grazer fish and the alga they graze on in the ecosystem. The fish population grows at first, until decreased by over fishing.





MF01a Grazing main interactions:

Consumption leads o algae death. Algae birth leads to higher supply. Supply leads to less death

of grazing fish by starvation and more grazer birth. MF01b grazing main assumption: Consumption is smaller than or equal to supply.

Entity	Quantity and Description
Marine ecosystem	A hypothetical marine ecosystem that contains fish and algae and that is being exploited by the fishing industry. Has no quantity.
Fishing industry	Any kind of fishing activity that exploits the fish population of the marine ecosystem. Quantity: Over fishing - this quantity means that more fish are being fished than being born; therefore it has a negative effect on the fish population size.
Grazing fish	Fish that feed on algae. Quantity: 1) Number of - representing the size of the fish population in the ecosystem. 2) Consumption - representing the rate at which the fish feed on the algae
Algae	Algae grazed by the fish. Quantity: Number of - representing the size of the algae population in the ecosystem.

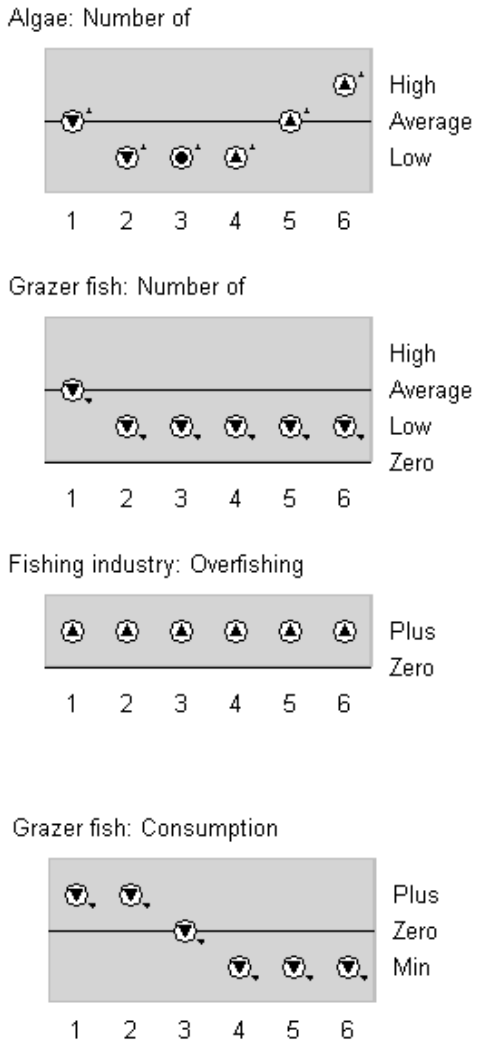
3.7.3. Quantity space definition (LS3-6)

Quantity	Quantity space	explanation
Over fishing	Zero, Plus	Over fishing either happens or it doesn't.
Number of (fish)	Zero, Low, Average, High	Over fishing may lead to extinction, so Zero is present. The three others (Low, Average, High) were chosen over just Low and high in order to create longer end paths in the simulation
consumption	Min, Zero, Plus	Consumption rate may be positive, negative or absent.
Number of (algae)	Low, Average, High	If Over fishing is Zero the fish may consume all the algae, leading to extinction. In such case the fish population should decrease as well. In order to simplify the LS2-4 models we decided not to show these grazer-algae dynamics, as this would require further relations between the fish and algae. Our LS2-4 models assume the alga is never extinct. The grazer-Algae dynamics are represented in the LS6 model.

3.7.4. Scenario

LS2 - 4 demonstrate the effect over fishing has on the marine ecosystem in a simplified way, where Grazer-Algae dynamics work in one way, where the fish affect the algae but not vice versa. The LS6 model further complicates the environment as it adds the two-way Algae-Grazer dynamics. LS2 - 6 models all show that when over fishing takes place, the fish population decreases and this leads to an increase in the algae population.

The following end-state is observed in the LS4 model:



At first the algae population decreases as it is consumed by the fish. As the fish population is decreased by over fishing the consumption rate becomes negative and the algae population begins to increase.

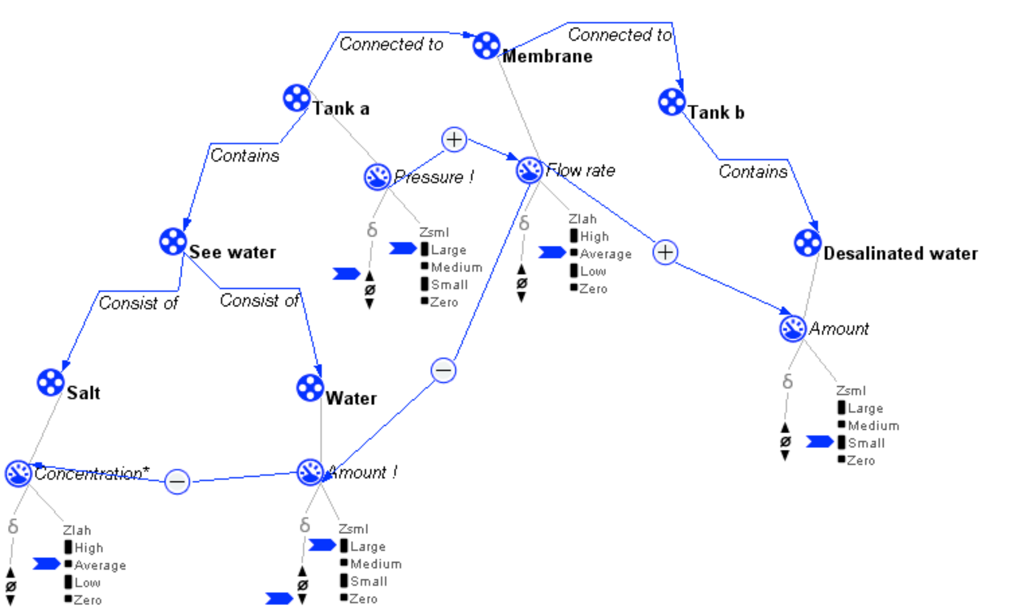
3.8. Reverse Osmosis for Sweetwater desalination

Theme / Topic	***land and water use / Drinking water supply***		
Author	***Moshe Leiba and Dror Zurel***	**Version(s)**	***DL v0.6.11(CM)***
Model	***Reversed Osmosis for Sweetwater Desalination - LS3***		
Target users	***Undergraduate students***		

Osmosis is a physical phenomenon that has been exploited by human beings since the early days of mankind. Osmosis is the transport of water across a selectively permeable membrane from a region of higher water chemical potential to a region of lower water chemical potential. It is driven by a difference in solute concentrations across the membrane that allows passage of water, but rejects most solute molecules or ions. Osmotic pressure (π) is the pressure which, if applied to the more concentrated solution, would prevent transport of water across the membrane. Forward osmosis uses the osmotic pressure differential ($\Delta\pi$) across the membrane, rather than hydraulic pressure differential (as in reverse osmosis), as the driving force for transport of water through the membrane. Osmotic pressure is the driving force for many present-day applications, from water treatment and food processing to power generation and novel methods for controlled drug release. In the field of water treatment, reverse osmosis is a more familiar process. Reverse osmosis uses hydraulic pressure to oppose, and exceed, the osmotic pressure of an aqueous feed solution to produce purified water (Sourirajan, 1970). In reverse osmosis, the applied pressure is the driving force for mass transport through the membrane (as opposed to the process of osmosis where the osmotic pressure itself is the driving force for mass transport). Numerous publications on the use of reverse osmosis for water treatment and wastewater reclamation appear in the literature.

3.8.1. Reverse osmosis LS3

Structure



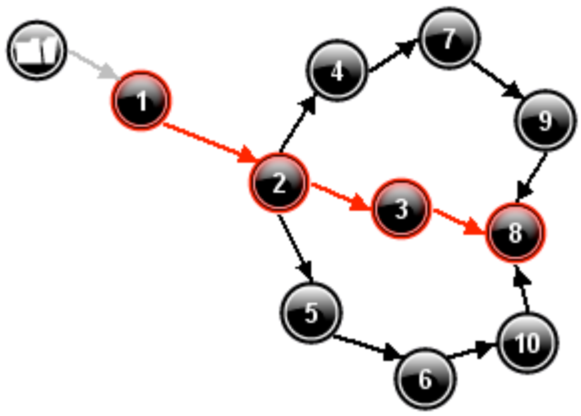
Entity	Quantity and Description
Tank A	Pressure
Membrane	Flow rate
Water	Amount
Desalinated water	Amount
Salt	Concentration

3.8.2. Quantity space definition (LS3)

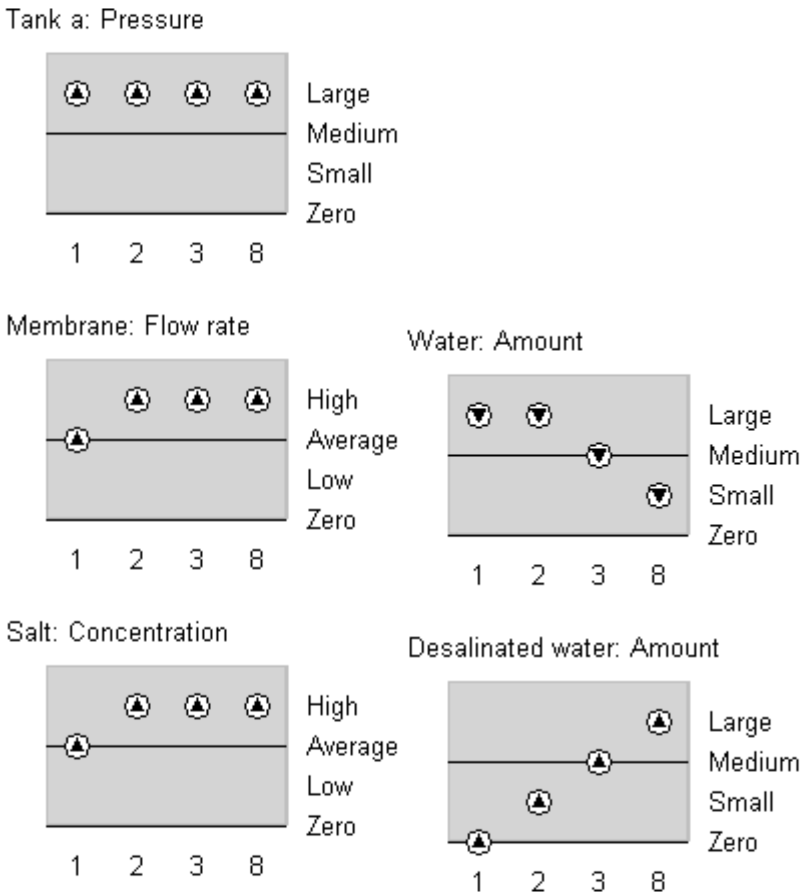
Quantity	Quantity space	Remarks
Amount	Zero, small, medium, large	Amount of water molecules
Concentaration	Zero, low, average, high	Concentration of salt in the water
Pressure	Zero, small, medium, large	Pressure on the membrane
Flow rate	Zero, low, average, high	Flow rate of water between the tanks

3.8.3. Scenario – reverse osmosis for sweetwater desalination

In this scenario seawater (which consists of water and salt) is filled in Tank A. The seawater then is transferred from Tank A to Tank B through a membrane to filter the salt. This process is called reverse osmosis.



The following end-state is observed in the LS3 model:



The seawater amount is decreasing while the salt concentration in the water rate is increasing. The flow rate is increasing and the desalinated water in tank B is increasing.

3.9. Aerobic and Anaerobic respiration

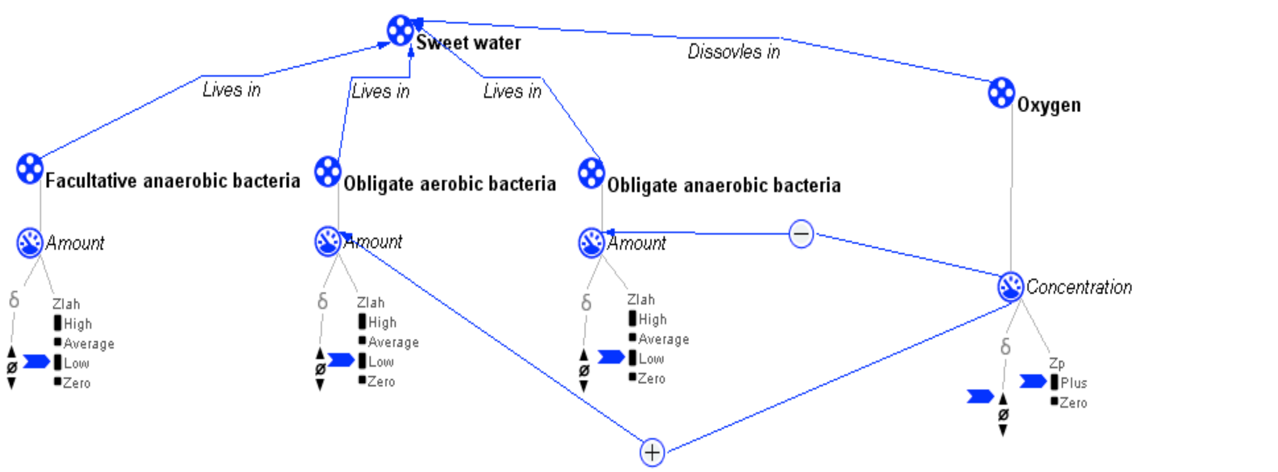
Theme / Topic	***energy resources and consumption / Anaerobic respiration***		
Author	***Moshe Leiba and Dror Zurel***	***Version(s)***	***DL v0.6.11(CM)***
Model	***Aerobic and Anaerobic Respiration - LS3***		
Target users	***Undergraduate students***		

Bacteria can derive the energy they need for growth from a considerable number of diverse and varied reactions, and the particular reactions utilized by a given organism can change depending upon the growth conditions employed (Haddock & Jones, 1977). Pasteur discovered that certain organisms are not only capable of growing in oxygen-free environments, but in many cases are restricted to such environments (Stanier et al., 1970).

An anaerobic organism or anaerobe is any organism that does not require oxygen for growth. It could possibly react negatively and may even die in its presence. There are three types: (1) obligate anaerobes, which cannot use oxygen for growth and are even strongly inhibited or killed by exposure to molecular oxygen; (2) aerotolerant organisms, which cannot use oxygen for growth, but tolerate the presence of it; and (3) facultative anaerobes, which can grow without oxygen but can utilize oxygen if it is present. Obligate anaerobes may use fermentation or anaerobic respiration. Aerotolerant organisms are strictly fermentative. In the presence of oxygen, facultative anaerobes use aerobic respiration; without oxygen some of them ferment, some use anaerobic respiration. An aerobic organism or aerobe is an organism that can survive and grow in an oxygenated environment. Obligate aerobes require oxygen for aerobic cellular respiration. These organisms use oxygen to convert biochemical energy from nutrients into adenosine triphosphate (ATP). Aerobic respiration requires oxygen in order to generate energy (ATP).

3.9.1. Aerobic and Anaerobic Respiration LS3

Structure



Entity	Quantity and Description
Facultative bacteria	Amount
Aerobic bacteria	Amount
Anaerobic bacteria	Amount
Oxygen	Concentration

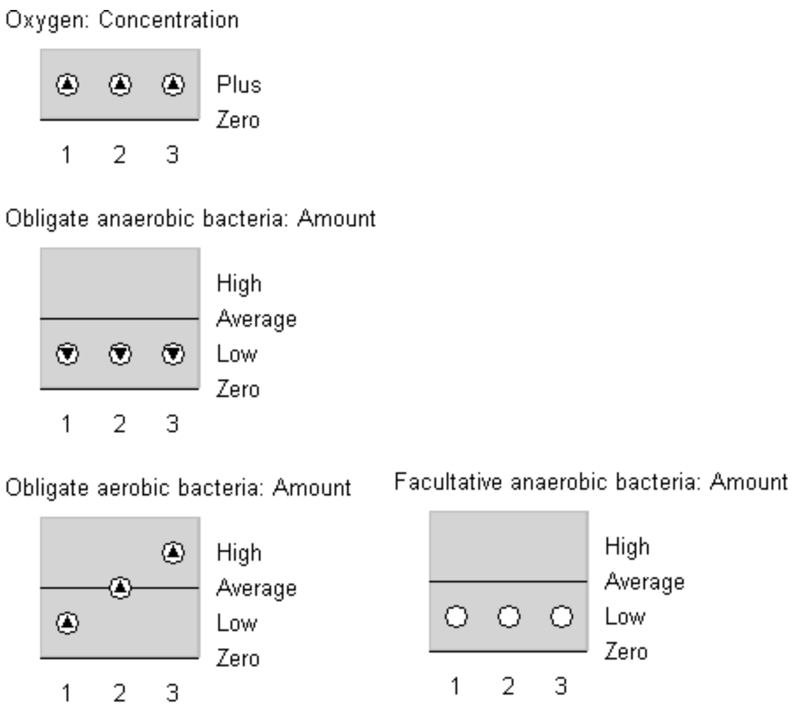
3.9.2. Quantity space definition (LS3)

Quantity	Quantity space	Remarks
Amount	Zero, small, medium, large	Amount of bacteria
Concentaration	Zero, plus	Concentration of oxygen in the water

3.9.3. Scenario – Aerobic and Anaerobic Respiration

In this scenario the constant presence of oxygen molecules in the seawater inhibits the growth of the obligate anaerobic bacteria and facilitates the growth of the obligate aerobic bacteria.

The following end-state is observed in the LS3 model:



Oxygen causes death to strict anaerobes and prevents deaths to strict Aerobes. Facultative bacteria can live in both ways, with or without oxygen.

4. Discussion

This deliverable presents the first set of 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 students.

TAU's models cover 9 different topics associated to the 7 main themes defined for DynaLearn's curriculum in Environmental Science. The models were designed at the different Learning Spaces (LS) provided in the DynaLearn workbench to enhance the potential for promoting learning. The models were implemented using LS2, LS3, LS4 and LS6, according to DL features at the different levels:

- LS2 allows to construct a Basic Causal model which enables simple representations of structural system and relationships. The modeller can construct simple models with several entities and quantities and progress to a more complex model. It can also allow to model the basic structure of the system with all the concepts involved and then to reduce the model to a more simple one (e.g., see "Shrimp and Goby symbiosis" or "Metabolism and acidity" models).
- LS3 allows to construct a Basic Causal Model and a State Graph. The use of the basic causal model with state graph enable the modeller to identify the thresholds values in ecological systems (e.g., see "Competition for space" or "Diving pressure" models).
- LS4 allows to construct 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 "TBT and Imposex" or "Over fishing" models).
- LS6 allows the to construct a model using a Generic and reusable knowledge. LS6 enable 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 (e.g., see "Adaptation to invasion" or "TBT and Imposex" models).

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, the shrimp and goby symbiotic relationship 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 ocean acidification 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. TBT), diving pressure or over fishing 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.

5. 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 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). More precisely, with the selection process of topics to be modelled. 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 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 DL. 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 different Learning Spaces, etc. are helpful insights for the further making of pedagogical decisions.

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