Final Paper

Human behaviors' impact on marine ecosystem and some fish behaviors

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1. Introduction

Continental shelf is the richest part of the ocean, with the world's most important fishing grounds. It is extends from the subtotal to the shelf bread while the outer edge of the continental shelf where depths drastically increase. The average depth for continental shelf is around 150m and varies in width from less than 1 km to over 750 km.

Fish have served as an important source of sustenance throughout human history. The earliest known fishing implements in archeological sites in Africa are over 90,000 years old. Fish have also served as an important catalyst for trade and exploration. Because the continental shelf is relatively shallow and due to the warm and temperate climate near the continental shelves the fish breed near the continental shelves. Therefore fishes are more productive here rather than in the open ocean and continental shelf has become the most important part for human's fishing industry. However, overfishing has become a quite hot topic currently which would be a disaster for the ecology cycle at that certain district.

Artificial Island at sea is also a quite popular phrase in the world now. They can be used to build airport which would not produce noise pollution in urban; easy to solve the pollution problem produced by large-scale cooling power provider; new city for people to live in and so on. However, the location's selection and its size are all have a big impact to the surrounding marine ecosystem.

At another part, with the rapid development of the modern agriculture and industry and increase of population, a large amount of waste are discarded into the sea which causing serious pollution of the oceans. These pollutions are mainly oil pollution, heavy metal pollution, organic pollution and so on.

2. Motivation

In my models, there are two main focuses. The first is how would human beings' behaviors impact on the ecosystem at continental shelf. In this study, I involved in 3 factors in total: building an island on the sea surface, fishing with boats moving around, emit wastes and pollution to the sea.

The second is the fishes' behavior. In this study, I implemented a lot of fishes' normal habits and its relationship with predators. I observe their moving patterns under several varied different situations. I also try to implement another kind of flock for schooling which base on the fish-swam algorithm for an addition model.

3.Model agents and behaviors

3.1 Rules for the agents

For forage fishes: it has the option to form a flock to act and move together which in the real world would help fish for reducing the resistance produced by water and would also help forage fishes to escape from its predators. Besides the flock feature, the fishes can also choose avoid action to detect nearby predators and escape to another direction. Every move would reduce their energy by one and if the possibility is big enough, they can reproduce which would cost them half energy. The hatch number is controlled by the fish-reproduce-percent slider. The fishes can eat seaweed and gain energy. And the energy is also determined by a slider named fish-gain-from-food.
For predators: They can chase after the forage fishes for food and if there is no fish nearby but some other predators nearby, they would fight with each other and one of them would die. Predators can eat fishes to gain energy and reproduce at a certain possibility that would lose half of its energy. If the age of predator is over 10 or its energy is less than 5, it would die. Every move would also make predator’s age plus one.

For human-beings: there is an option to decide whether the human would be involved in this ecosystem. If human-involved is false, the system would only have predators and forage fishes which would form a balanced ecosystem. If human-involved is true, the system would have boats moving around and catching predators and fishes. The boats’ speed is higher than fishes and when there is a predator nearby, the boat would prefer catching a predator rather than all the fishes in radius 3.
For plankton: Their color is green. Forage fishes are feed on the planktons. And planktons can regrow randomly in a certain amount of time. When they are eaten by the fishes, they would disappear and pcolor would go back to blue.

3.2 According to the realisitc

For forage fishes:
In a real marine ecosystem, small fishes would form a flock for three reasons: 1. Make the process of seeking for more food; 2. Confuse its predators with huge amount to have a higher survival possibility; 3. Forming a flock and after its teammates would reduce the resistance produced by the water while moving. If a predator were coming nearby, the small fishes would all react as avoid and escape. And when the predator is gone, they would form a schooling again. In the real world, forage fish often make great migrations between their spawning, feeding and nursery grounds. Schools of a particular stock usually travel in a triangle between these grounds. For example, one stock of herrings has their spawning ground in southern Norway, their feeding ground in Iceland, and their nursery ground in

northern Norway. Wide triangular journeys such as these may be important because forage fish, when feeding, cannot distinguish their own offspring. For example, Salmon is one of these fishes that would make such great migrations for reproducing. To simplify my model, I make all the grounds to be the sources as the only places that forage fishes can reproduce.

For predators:

In the real world, if there were enough fishes around, they would prefer chasing and eating the fishes. Otherwise, they would defense their place and fight with other predator until one of die or escape. Also, they would gain energy from their food to maintain their normal living. The predators would reproduce quite low numbers of small predators comparing to the forage fishes'. And they would also face the fight for space problem. Predators would die if they do not have any food for a long time or if they are too old to fight for place and food.

For human's fishing:

Apparently, big fish like sharks and tuna are more expensive and more popular in human market. So fisherman would have a preference on catching the predators in the real world. They would move around and if there were any predator around, they would catch the predators. If there were only small fishes around, they would catch big amounts of them instead.

For plankton:

They are the main food for forage fishes and it's also the role as producer in the real world. So with water and sunshine, they would reproduce randomly by themselves.

The plankton would have two features influenced by the pollution: 1. Rapidly grow and use out all the oxygen in the water and make the fishes die for cannot breathe. 2. Die out at that certain place and do not grow until it returns to the clean state. As my model does not take oxygen into account, we only focus on the second rule.

3.3 Activities in the model

Drawing an island:

The users can turn a patch into color red, which means building an island on the ocean. These parts are not accessible by any kinds of fish or boats.

We can use this feature to study how would the size of the island effect all the ecosystem around continental shelf.

Emit pollution:

The users can turn a patch into color grey, which means make that part of ocean too dirty for plankton to live on. So at the grey patches, plankton would not grow there. However, the ocean has an ability to clean it self. When the water turns back to blue the plankton would regrow again.

Fish migrations:

The users can turn a patch into color pink, which means it is a place for forage fishes to reproduce. No forage fish can reproduce at plankton or blue. We can draw several sources for fishes and observe their movings.

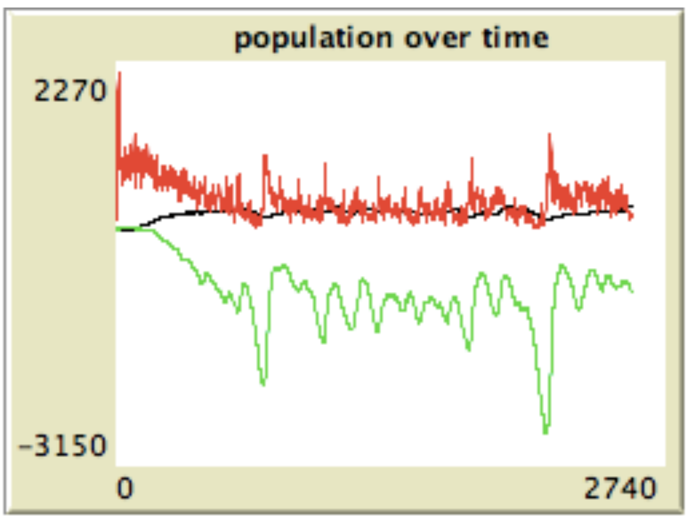
4. Data Analysis

Analysis how human's fishing and other behaviors matters

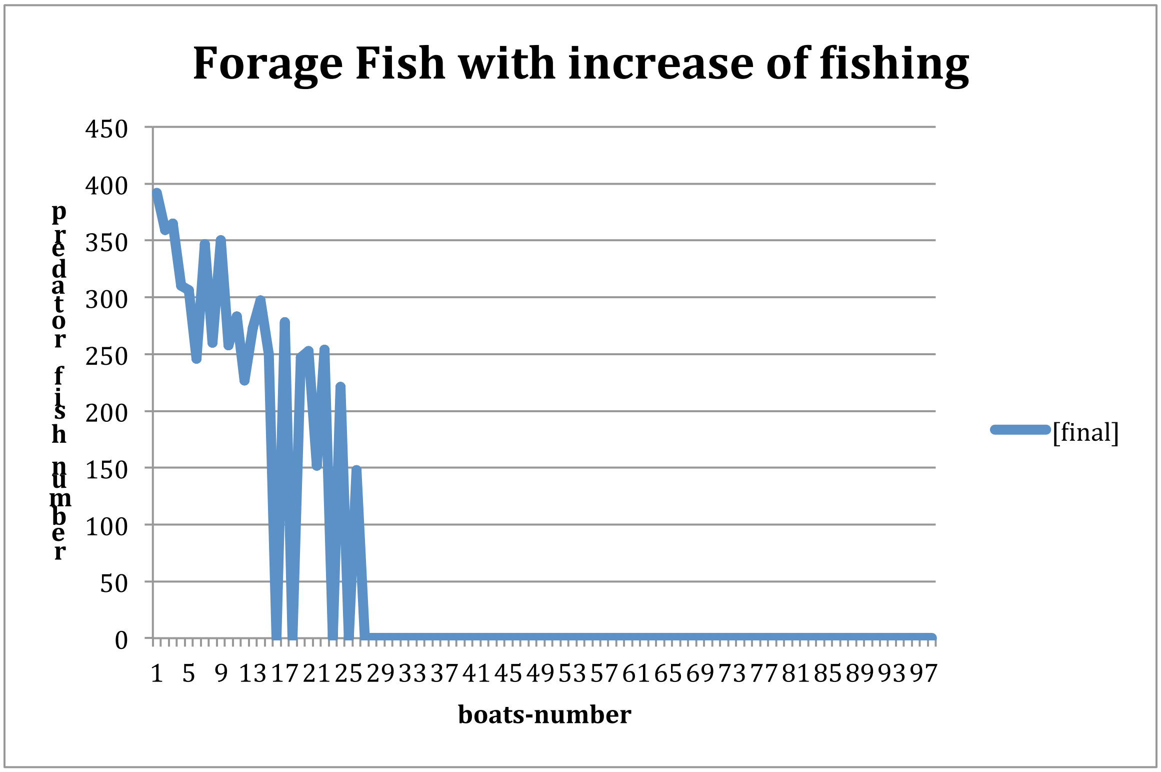
The amount of the fishing activities would certain have an affect on this marine ecosystem. But what is the range of this? What would happen if people increasing their activities to catch more fishes?

4.1 Balance example

In my model, with about 11 boats moving around on the surface and go fishing would still make the whole ecosystem balanced. (The red line is the population of forage fishes and the black line represents the number of predators, the green line is the sum of plankton dived by 30)



From this figure, we can find that within a certain amount of fishing activities, forage fishes, predators, plankton and human beings can reach a balance.



4.2 Changing the boats number

With former model, we can see the amount of fish decrease dramatically if human fishing behavior increases.

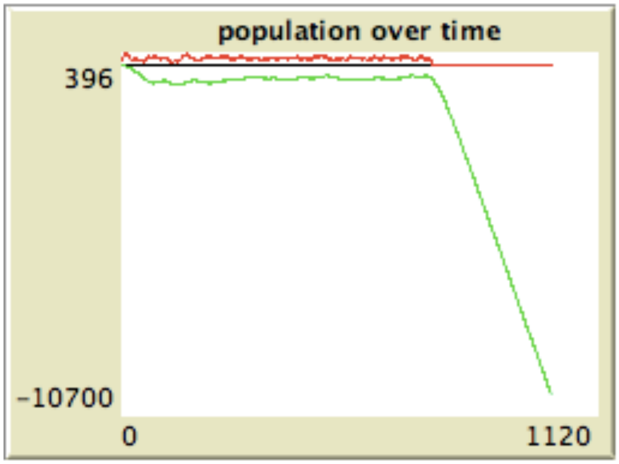
This relationship is like exponential, the reason is because fishing cause fish dying thus less fish can reproduce, this influence spread over the whole world of fish.

In the real world, we can use a more complicated model to determine the proper fishing allowance.

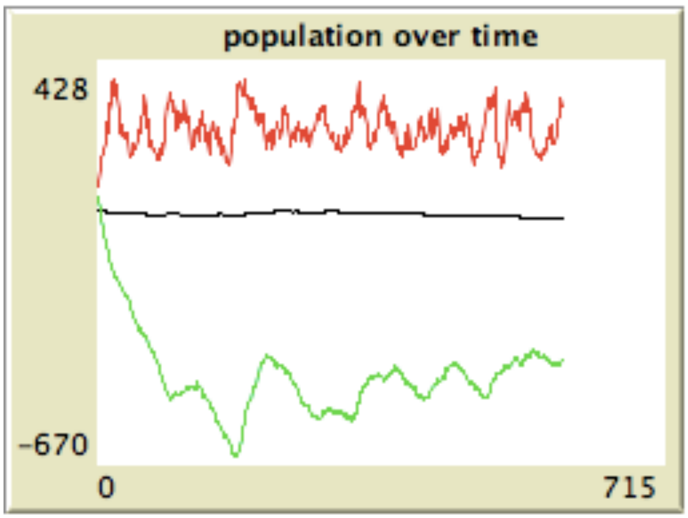
4.3 Prefer big fishing

We can change another variable, prefer-big?, which means whether the human fishing behavior is more prefer on catching big fish rather than a large amount of forage fishes. We still choose the boats number to be 11 which has been a balanced case presented earlier.

So after changing the prefer-big? Switcher from off to on, we have the following results:



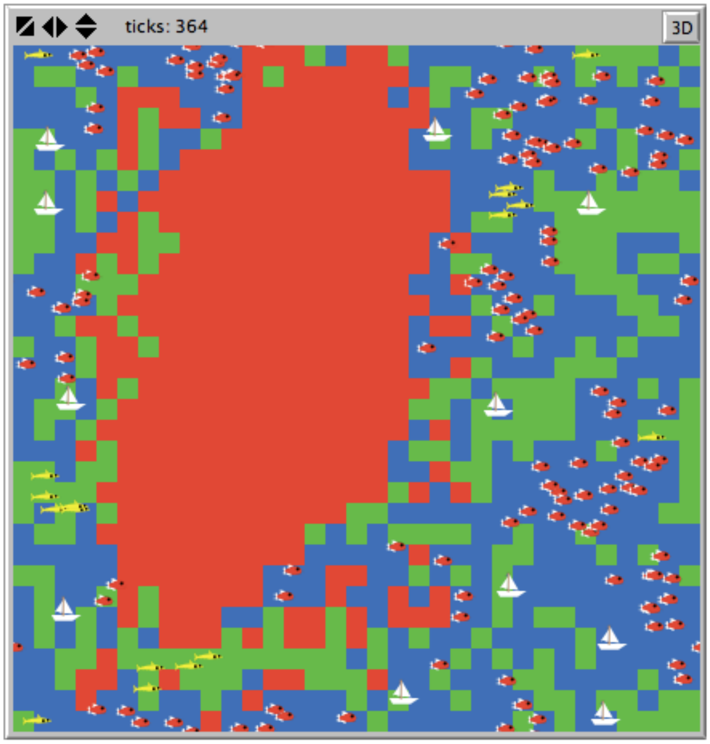
The result may not be very clear, I will show another state during the process.



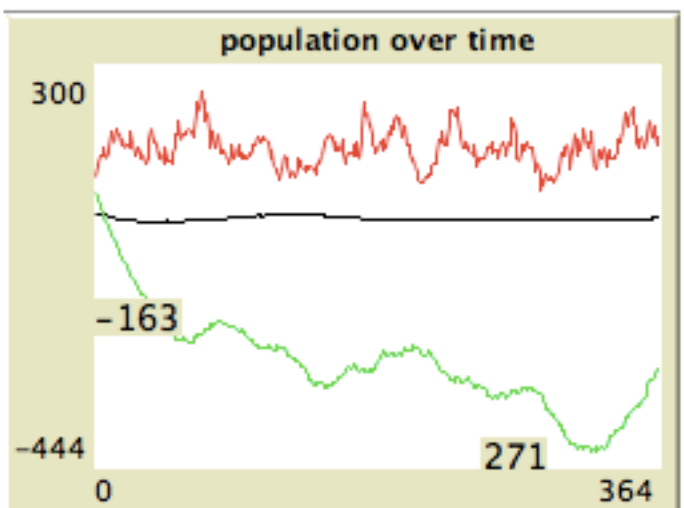
We can see the slight differences from the balanced one. In the balanced plot, the black line, which presents the number of predators, it slightly grows up and declined a little by the time and reach a loop. In this plot, we can see that even though the black line seems to be very gentle, its overall tendency is going down. The relationship is pretty clear; human's fishing prefers the predators and breaks the balance among forage fishes, predators and boats. Without evenly catching these two kinds of fishes, predators would die out pretty soon. And after the predators' die out, the forage fishes would die out quickly (because even though the boats can only catch one predators a time, they can catch all the forage fishes in radius 3).
And this data suggests that we cannot over fishing for only one or several kinds of fishes. It is very likely that one piece of species dies out would lead to a sequence of disasters.

4.3 Draw island model

With keeping all the same setting as the balanced model, I just draw some island on the screen and make it unable to access by turtles like following:



After we running some time, we get the following plot:



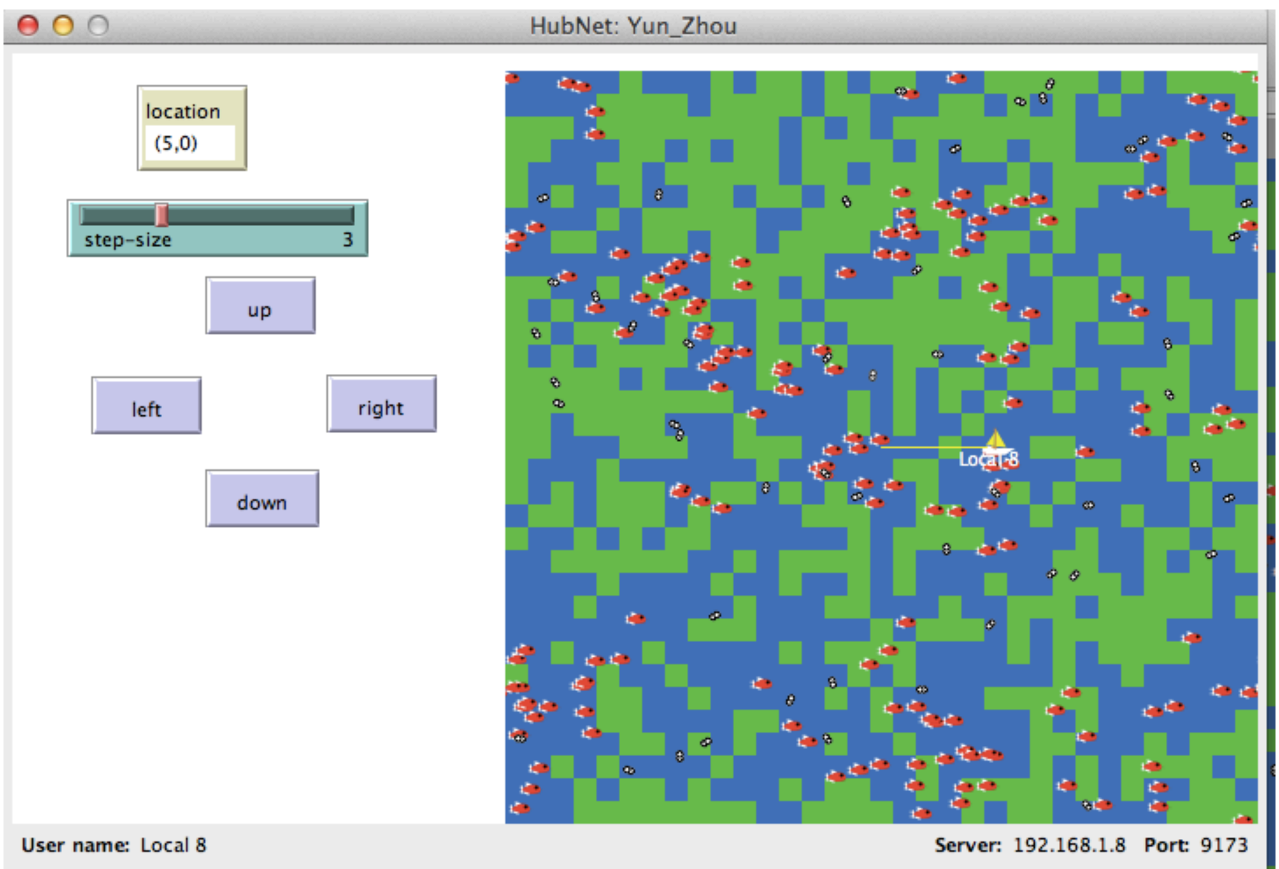
Apparently, the amount of forage fishes is much smaller than it in the balanced model. And behaviors of the fishes are more closed to the patterns they act in a real continent shelf ecosystem (which watch from the videos online).

In addition, the amount of plankton has declined a lot. As our analysis here, with less space to move and seeking for food, the density of the fishes has increased dramatically. So even though the plankton keep on regrow, its eaten chance has increased a lot. Thus the total amount of the plankton has decreased.

There are also some other interesting phenomena for combining two or more features together. I will not include them here.

5.HubNet Model

For the HubNet project, we can control a boat and moving around for fishing which follow the rules. In this project, we can clearly sense that only add one boat, there would merely have affects on the whole ecosystem. But when users are growing and moving their boats chasing after the predators (which is more valuable in my definition), the predators would die out pretty quickly. And if the users' amount is big enough, we can fish all the forage fishes also(it would a little difficult, for you have possibility for catching nothing and the fishes are moving pretty fast).



6.Model Extension

In the main model, I have two extensions.
The first is the phenomenon that some kind of fish would trace back to a certain place for reproducing. So in this extension, forage fishes would only reproduce at a certain place drawn by users. And if they are far away from that place, they would swim back and still try to produce there. And this behavior called fish migrations.
In the real world, forage fish often make great migrations between their spawning, feeding and nursery grounds. Schools of a particular stock usually travel in a triangle between these grounds. For example, one stock of herrings has their spawning ground in southern Norway, their feeding ground in Iceland, and their nursery ground in northern Norway. Wide triangular journeys such as these may be important because forage fish, when feeding, cannot distinguish their own offspring. For example, Salmon is one of these fishes that would make such great migrations for reproducing.
In the following feature, I simplify the rules and draw four sources for the fishes to make migrations. And the movements are like fishes moving around among these four places and the place with the biggest size would have the biggest average amount of fishes.

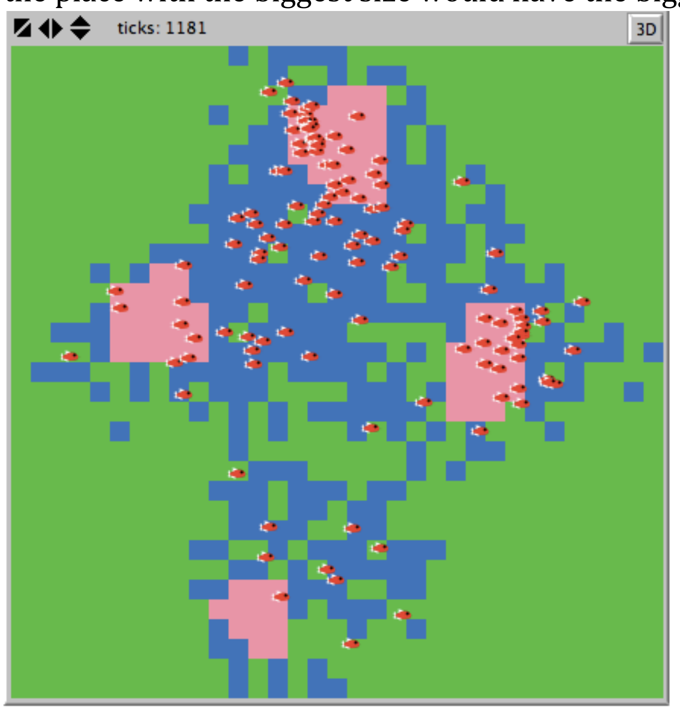


Figure : Shows a simple phenomena produced by my model

Following, I will add more characters in this extension. I introduce some predators and see what predators would act.

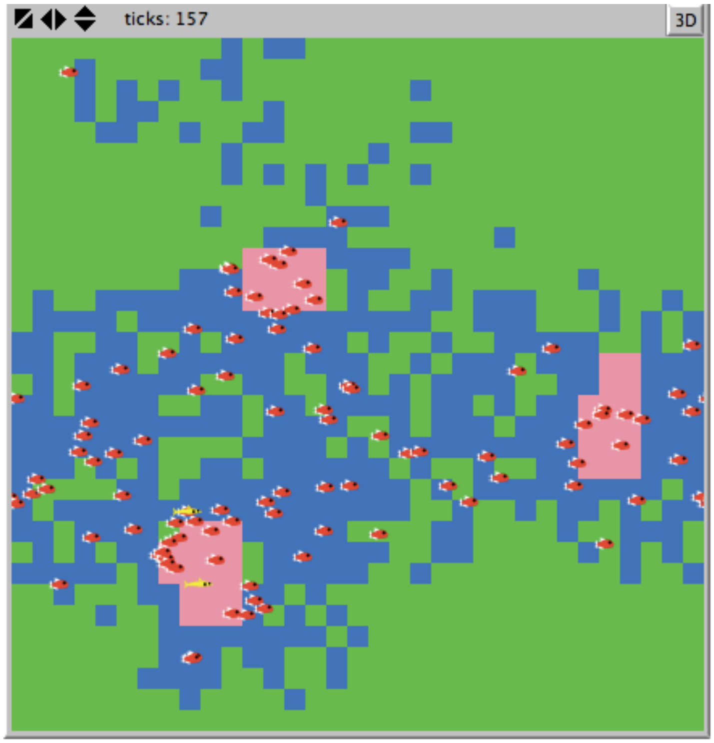
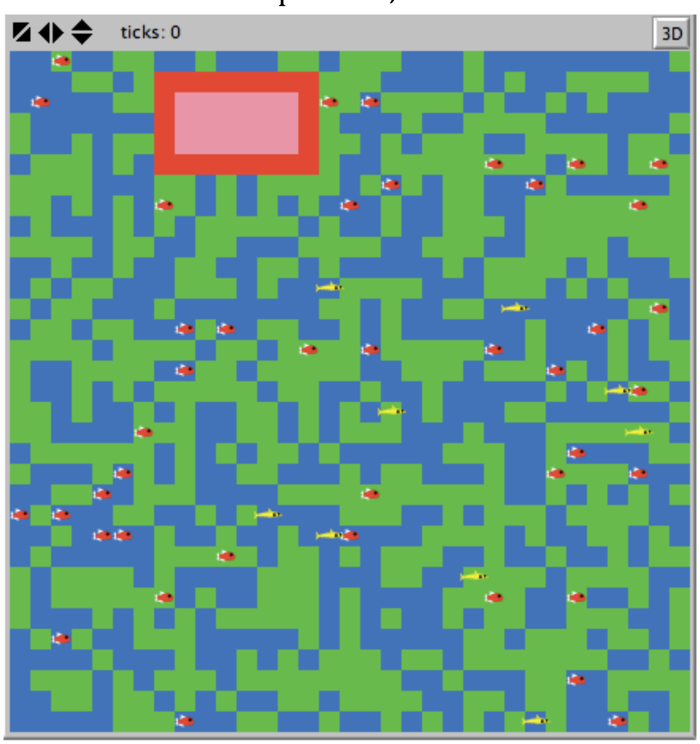


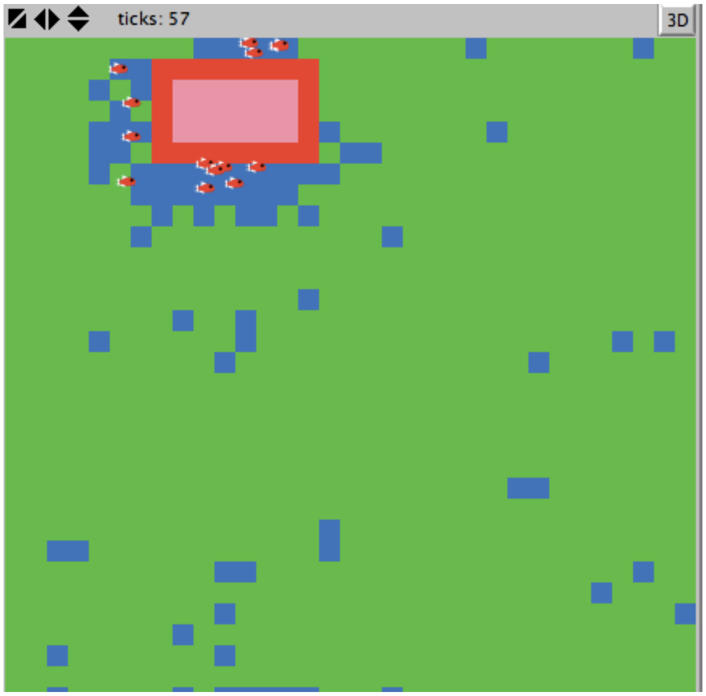
Figure : Shows a phenomena with two agents produced by my model

After a certain time ticks, predators would stay around at one of the sources where there are always enough food for them and there would also have no fights between them.

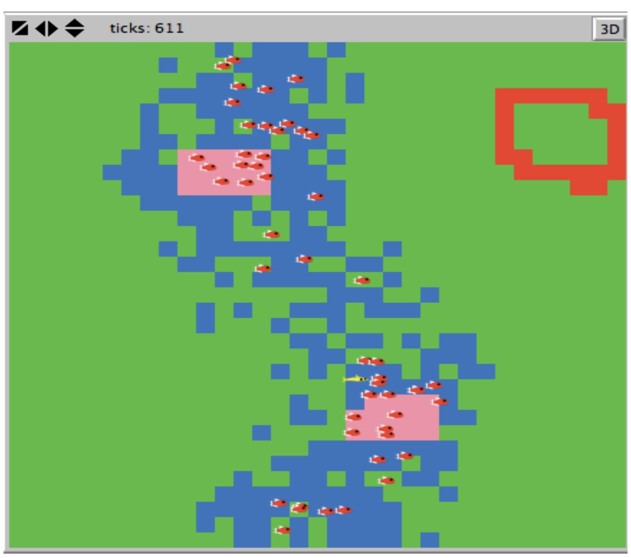
So what if I build some island around the sources?

I have attached two pictures, the first is for the start state and the second is for the end state.



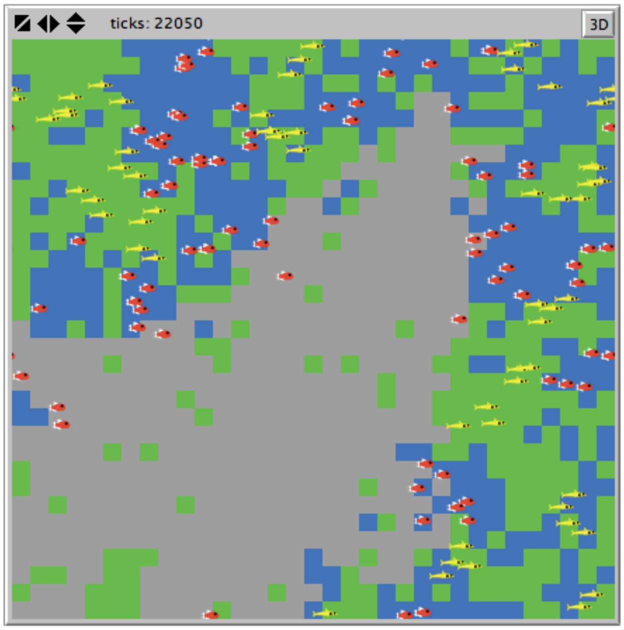


We can clearly see that, when we occupy the place where forage fishes used to reproduce, both forage fishes and predators would go out pretty quickly.
And when we build our island at other places, it would return to the normal phenomena that fishes moving around among sources and predators follow the schoolings for feeding on them.



The second extension is about pollution.
In this model, I make users can draw some special patches into color grey and make them unable for plankton's regrowth.

Without plankton, forage fishes and predators would rarely enter that part of ocean.



And clearly, the amount of forages fishes and predators declined a lot.

Additional model

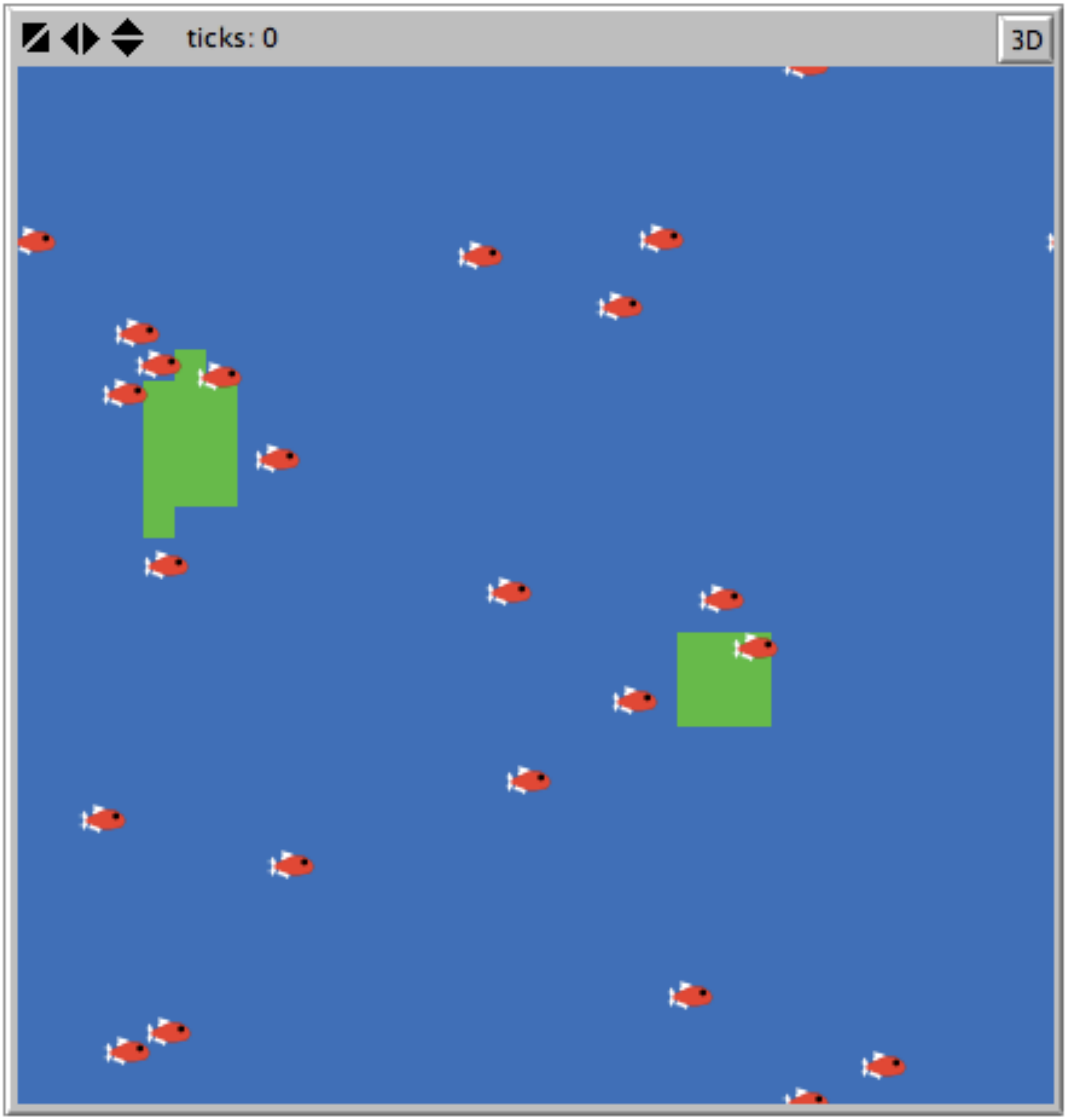
In my additional little model, I try another kind of flock----schooling. In this behavior, it has a specific algorithm named artificial fish-swam algorithm as following:

Algorithm 1 fish swarm intelligent algorithm

Input: m, l, u, $nfe_{\max}$, ε, δ, μ_δ, θ, η
iteration $\leftarrow$ 1; $\tau \leftarrow 1$
$(x^1, \ldots, x^m) \leftarrow Initialize()$
while termination criteria are not satisfied **do**
  for $i = 1, \ldots, m$ **do**
    Compute the "visual"
    if *visual scope* is empty **then**
      $y^i \leftarrow Random(x^i)$
    else
      if *visual scope* is crowded **then**
        $y^i \leftarrow Search(x^i)$
      else
        if central point is better than x^i **then**
          $y_1^i \leftarrow Swarm(x^i)$
        else
          $y_1^i \leftarrow Search(x^i)$
        end if
        if best function value is better than $f(x^i)$ **then**
          $y_2^i \leftarrow Chase(x^i)$
        else
          $y_2^i \leftarrow Search(x^i)$
        end if
        $y^i \leftarrow \arg\min\{f(y_1^i), f(y_2^i)\}$
      end if
    end if
  end for
  for $i = 1, \ldots, m$ **do**
    $x^i \leftarrow Select(x^i, y^i)$
  end for
  if iteration $> \tau m$ **then**
    if "stagnation" occurs **then**
      Randomly choose a point x^l
      $y^l \leftarrow Leap(x^l)$
    end if
    $\tau \leftarrow \tau + 1$
    $\delta = \mu_\delta \delta$
  end if
  iteration $\leftarrow$ iteration + 1
end while

As the time limits, I only make three simple behaviors: searching behavior, chasing behavior, leaping behavior. And the definition is as following:
searching behavior - when the fish discovers a region with more food, it will go directly and quickly to that region;
chasing behavior - when a fish in the swarm discovers food, the others will find the food dangling after it;
leaping behavior - when fish stagnates in a region, a leap is required to look for food in other regions.

And these rules would give me some interesting phenomena, like following:



7. References

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

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[3]Pinet, Paul R. (1996) Invitation to Oceanography. St. Paul, MN: West Publishing Co., 1996. ISBN 0-7637-2136-0 (3rd ed.)

[4] http://en.wikipedia.org/wiki/Fish_migration

[5] ^ Barbaro1 A, Einarsson B, Birnir1 B, Sigurðsson S, Valdimarsson S, Pálsson ÓK, Sveinbjörnsson S and Sigurðsson P (2009) "Modelling and simulations of the migration of pelagic fish" Journal of Marine Science, 66(5):826-838.

[6] Edite M. G. P. Fernandes, Tiago F. M. C. Martins2 and Ana Maria A. C. Rocha: Fish Swarm Intelligent Algorithm for Bound constrained Global Optimization

[7] http://library.thinkquest.org/CR0215471/ocean_pollution.htm