# Modeling and Evaluating Consequences of Overfishing


## Marissa Mocenigo, Sam Wood, Jenny Chen

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## Abstract

Evaluating the issues and solutions in sustainable fishing requires an in-depth and multidisciplinary analysis. Our project is divided into three distinct tasks: researching the problem at hand, examining math models on population data and developing an application to analyze the results and raise awareness for a potential solution.

Ultimately, fishing quotas are most commonly used to reduce the impact of overfishing; however, few other options and exist, and fishing quotas are not reliable solutions. Math modeling can be used to show the changes in population and species distribution. Our project examined the Lotka Volterra model, the Nicholson Bailey model, Maximum Entropy models, and their applications in sustainable fishing.

Based on these models and the known issues in sustainable fishing, we built a few small applications to examine solutions to the overfishing problem. These applications are meant both to raise awareness about sustainable fishing and to help policy-makers analyze the risks and benefits that their policies will have on the fish populations.

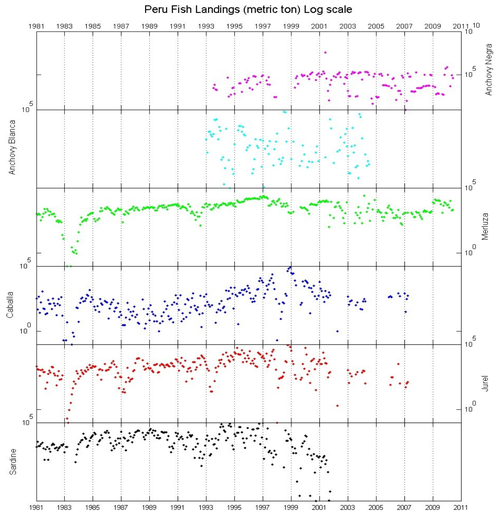

## Current Issues in Sustainable Fishing

Overfishing is one of the biggest threats to the marine ecosystem. Problems have multiplied on account of improved technology.

- Boats with sonar that can detect large schools of fish.
- "More than 70 of the world's fisheries are 'fully exploited', 'over exploited' or significantly depleted'."

Widespread impact due to human demand and negligence.

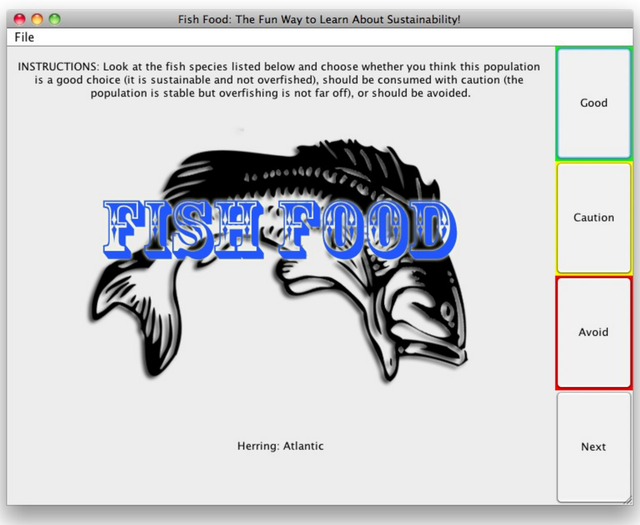
- Many species depleted or extinct.
- Predator/prey relationships are damaged by depletion.
- Fishery employees are jobless after population collapse.
- In 1992, the cod fishery in Newfoundland, Canada collapsed causing over 40,000 people to lose their jobs.



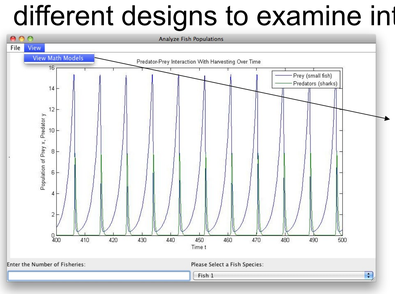

## Application Design

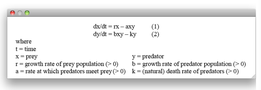
Fish Food: The fun way to learn about sustainability!

- An important and difficult task of sustainability research is raising awareness on the issues.
- Fish Food teaches children about at-risk species.
- Players must guess which fish are good to eat.
- This knowledge can be applied at home.
- The data is based off research from the Monterey Bay Aquarium.

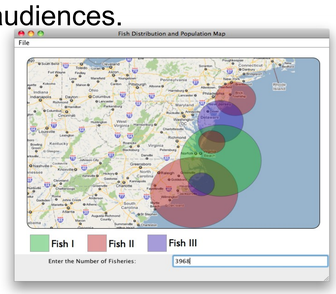



Policy-makers and scientists who are researching overfishing issues will want an application that shows the mathematical analysis of the fish populations and changes due to overfishing; however, such an application would not appeal to a broader audience. Consequently, we created a few different designs to examine interfaces for different audiences.

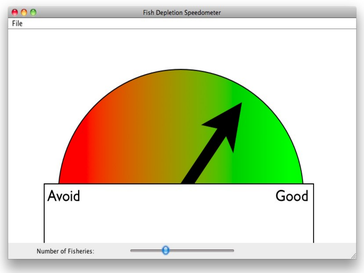


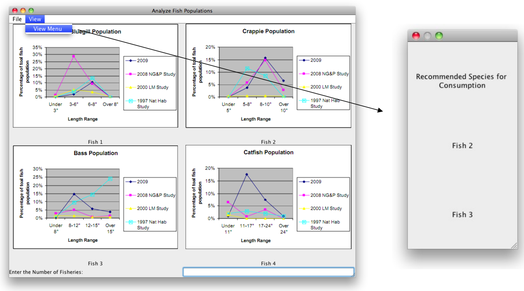

Layout 1




Layout 2




Layout 3







Layout 4

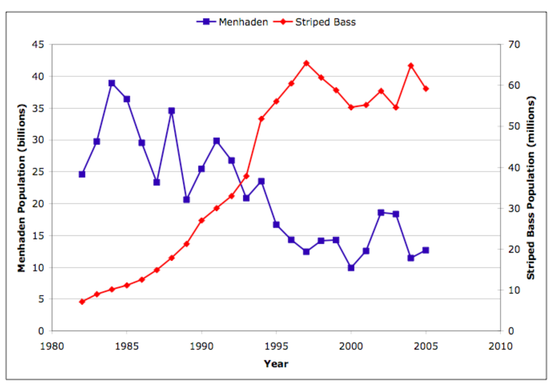
| | Layout 1 | Layout 2 | Layout 3 | Layout 4 |
|---|---|---|---|---|
| **Advantages** | - Geared toward policy-makers, scientists, and other users making a mathematical analysis<br>- Displays population graphs of individual species based on a given number of fisheries<br>- Allows for further evaluation through analysis of the math model | - Offers a large amount of information in a small frame<br>- Easy to use and appeals to a wide audience<br>- Great visualization tool to grab attention | - Easy to use and read<br>- Interactive and good for children and schools teach about sustainability | - Offers a large amount of information<br>- Appeals to a wide audience, including more scientific communities<br>- Great visualization tool to grab attention |
| **Disadvantages** | - Less aesthetic but more analytical<br>- Appeals to a specialized audience, not accessible to a wide scope of users | - Less technical and analytical information will not persuade policy makers<br>- With the addition of many species the view can get cluttered quickly | - Very simplistic<br>- Will only appeal to a small audience<br>- Very little precision in calculations | - Evaluation method is not very transparent<br>- Different sections appeal to very different audiences with little cohesion |

## Math Models

Lotka-Volterra Model

$$dx/dt = rx - axy$$
$$dy/dt = bxy - ky,$$

where
t = time
x = prey
y = predator
r = growth rate of prey population (> 0)
b = growth rate of predator population (> 0)
a = rate at which predators meet prey (> 0)
k = (natural) death rate of predators (> 0)




## Conclusion

Spreading awareness is vital to controlling overfishing. Our research and analysis show that the marine ecosystem could still be restored if the correct measures are taken. By creating the four layouts we were able to cover a large group of people ranging from children to policy makers. The game is also a fun and effective tool to teach people of all ages. We hope by effectively spreading awareness and following policies and protocols will benefit the fish populations, marine ecosystem, as well as fishing industries.


## Acknowledgments

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## References


C. Clark. 2006. The Worldwide Crisis in Fisheries. New York: Cambridge University Press.
C. Costello, S.D. Gaines, and J. Lynham. 2008. Can catch shares prevent fisheries collapse? Science 321(5896): 16781681.
G. Heal, and W. Schlenker. 2008. Sustainable Fisheries. Nature 455(7216): 10441045.
B. Worm, E.B. Barbier, N. Beaumont, J.E. Duy, C. Folke, B.S. Halpern, J.B.C. Jackson, H.K. Lotze, F. Micheli, S.R. Palumbi, E. Sala, K.A. Selkoe, J.J. Stachowicz, and R.Watson. 2006. Impacts of biodiversity loss on ocean ecosystem services. Science
314(5800): 787790.
B. Worm, R. Hilborn, J.K. Baum, T.A. Branch, J.S. Collie, C. Costello, M.J. Fogarty, E.A. Fulton, J.A. Hutchings, S. Jennings, O.P. Jensen, H.K. Lotze, P.M. Mace, T.R. McClanahan, C. Minto, S.R. Palumbi, A.M. Parma, D. Ricard, A.A. Rosenberg, R. Watson, and D. Zeller. 2009. Rebuilding global Fisheries. Science 325(5940): 578585.
J.Hofbauer and K.Sigmund. Evolutionary Games and Population Dynamics. Cambridge University Press, June 1998.
A.Hollowed, N.Bax, R.Beamish, J.S. Collie, M.Fogarty, P.Livingston, J.Pope, and J.Rice.
Are multispecies models an improvement on single-species models for measuring fishing impacts on marine ecosystems? 57(3):707719, 2000.
V.Kapur, D.Troy, and J.Oris. A sustainable fishing simulation using mathematical modeling and database access through the world wide web. Crossroads, 4(1):912, 1997.
F.Micheli, P.Amarasekare, J.Bascompte, and L.R. Gerber. Including species interactions
in the design and evaluation of marine reserves: Some insights from a predator-prey model. Bulletin of Marine Science, 74:653669, May 2004.
M.Peschel and W.Mende. The predator-prey model: Do we live in a Volterra world? Springer, Wien, New York, 1986.
Beder, Sharon. Environmental principles and policies : an interdisciplinary introduction.2006.
Ahmed Seffah, Jan Gulliksen and Michel C. Desmarais. Human-centered software engineering - integrating usability in the software development lifecycle. 2005.
http://www.asmfc.org/
http://www.edf.org/article.cfm?ContentID=5098
http://innovation.edf.org/page.cfm?tagID=30957
http://ec.europa.eu/fisheries/cfp_en.htm
http://www.edf.org/documents/7286_WegmansFarmedShrimpStandardsOct2007.pdf