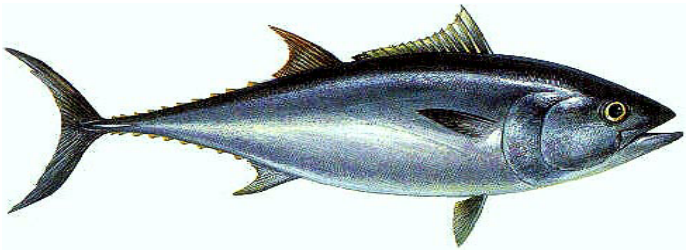
ICE - Functions, Rates of Change

The giant bluefin tuna (*Thunnus thynnus*) is the largest bony fish known to science. This fish can grow to a length of eleven feet and weigh up to 1500 pounds[1]. The bluefin tuna is a remarkably strong fish, and is able to retract its fins *and eyes* to make it more streamlined. Bluefin tuna have been observed to swim at speeds of up to 55 miles per hour[2].

Bluefin tuna are valued as a food source, especially as sushi and sashimi. A large tuna in excellent condition may bring as much as $80,000 when sold at auction in Tokyo[3]. Bluefin have been commercially fished in the western Atlantic since the 1960's, with the industry firmly established by the 1980's[4]. Bluefin fishing has become such a lucrative business that commercial tuna fishermen routinely use spotter aircraft to find the fish[5].



Contrary to many perceptions[6] most tuna species are not seriously over-fished[7], although they are heavily exploited. Bluefin tuna have been heavily over-fished for at least twenty years[8]. Based on studies conducted by the International Convention for the Conservation of Atlantic Tuna (ICCAT) and the National Research Council (NRC), the breeding population of Atlantic bluefin tuna fell from approximately 235,000 in 1975 to less than 40,000 in the late 1990's.

In 1998, ICCAT proposed an historic plan to limit catch sizes of bluefin tuna to allow the population to recover. Projections suggest that the tuna population will require twenty to thirty years to reach the numbers of tuna that existed in the mid-

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[1] Source: New England Aquarium (www.neaq.org). The largest bluefin tuna on record was caught by Ken Fraser in Canada during 1979. The fish that Fraser caught weighed 677 kg (1497 pounds).

[2] Source: World Wildlife Fund. (www.panda.org).

[3] Source: NASA and the Smithsonian Institution Ocean Planet Project (seawifs.gsfc.nasa.gov).

[4] Source: National Academy of Sciences, National Research Council. *An Assessment of Atlantic Bluefin Tuna*. Washington, DC: National Academy Press, 1994.

[5] Source: World Wildlife Fund.

[6] For example, see: Cole, J. N. "The Vanishing Tuna." *Atlantic Monthly*, Volume 239, p. 50. (Dec. 1976)

[7] Source: Environmental Protection Agency, Revised Final Enviromental Impact Statement to accompany Fisheries Management Plan for Highly Migratory Species, 1999.

[8] Source: Buck, Eugene. "Atlantic Bluefin Tuna: International Management of a Shared Resource." The National Council for Science and the Environment, Washington DC, 1995.

1970's[9]. In this ICE, you will model the growth of the bluefin tuna population and investigate the predictions of the NRC and ICCAT.

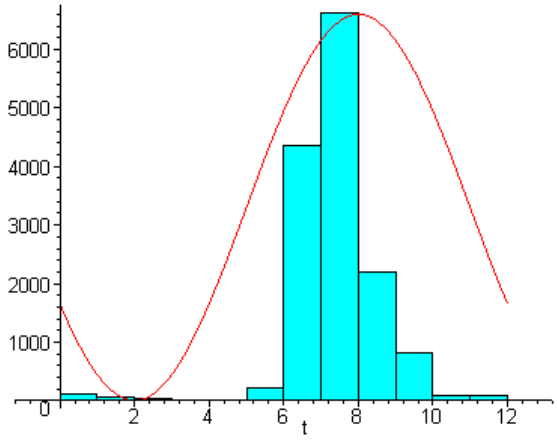

Figure 1: Number of bluefin tuna caught by month, 1998.

The commercial bluefin fishing season runs from June 1 to May 31, or until the quota has been reached[10]. Most fish are caught between July and October, with relatively few fish harvested during the rest of the year[11] (see histogram in Figure 1). The rate at which tuna were caught by fishermen during 1998 is also shown in Table 1 (below).

Although relatively little is known about the life history of the bluefin tuna, studies by the National Academy of Sciences and the New England Aquarium suggest that if the bluefin tuna were left alone then their population would grow at a rate given by the equation:

$$\frac{dP}{dt} = 0.0875 \cdot P(t)$$

where t represents the number of months since January 1998, and $P(t)$ is the bluefin tuna population (measured in units of thousands of tuna).

Month	Rate at which bluefin tuna caught during 1998 (thousands of tuna per month)
January	0.105
February	0.050
March	0.023
April	0.013
May	0.013
June	0.229
July	4.371
August	6.633
September	2.209
October	0.809
November	0.088
December	0.080

Table 1.

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[9] Source: National Academy of Sciences, National Research Council. *An Assessment of Atlantic Bluefin Tuna*. Washington, DC: National Academy Press, 1994.

[10] Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. "Small Entity Compliance Guide for the Consolidated Regulations of Atlantic Tuna, Swordfish, Sharks and Billfish." 1999.

[11] Source of data: Personal communication from the National Marine Fisheries Service, Fisheries Statistics and Economics Division, Silver Spring, MD.

- ***The net rate at which the bluefin tuna population will grow will be the natural population growth rate (i.e. the growth rate if the tuna were left alone) minus the rate at which the tuna are caught. Use this along with the information given in Table 1 to complete the table given below.***

Months since January 1998	Number of Bluefin Tuna (thousands of tuna)	Net growth rate of tuna population (thousands of tuna per month)	Amount tuna population will change in next month (thousands of tuna)	New tuna population (thousands of tuna)
t=0				
t=1				
t=2				
t=3				
t=4				
t=5				
t=6				
t=7				
t=8				
t=9				
t=10				
t=11				
t=12				

- ***Based on the entries in your table, how would you describe the impact of the ICCAT regulations on the bluefin tuna?***

- ***In theory (there is no need to actually do the calculation - although in Xb you will learn how to do this much more easily), how could you determine the length of time required for the bluefin tuna population to return to 235,000 tuna?***