PREDICTING THE COLLAPSE OF A FISH STOCK

The case of the Atlanto-Scandian herring

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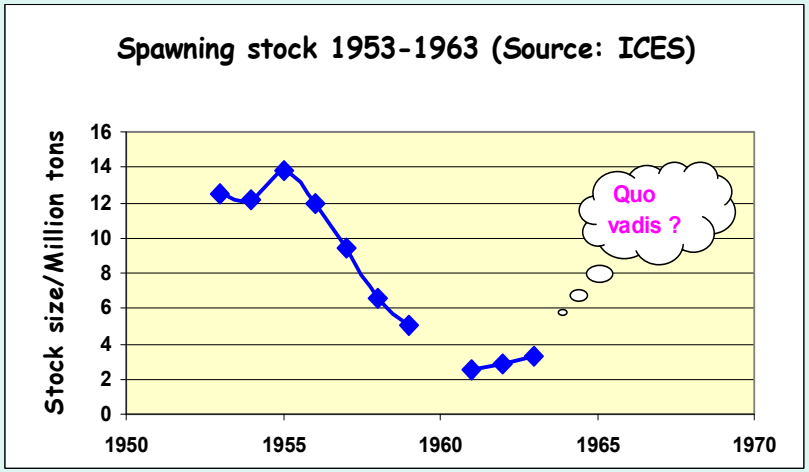
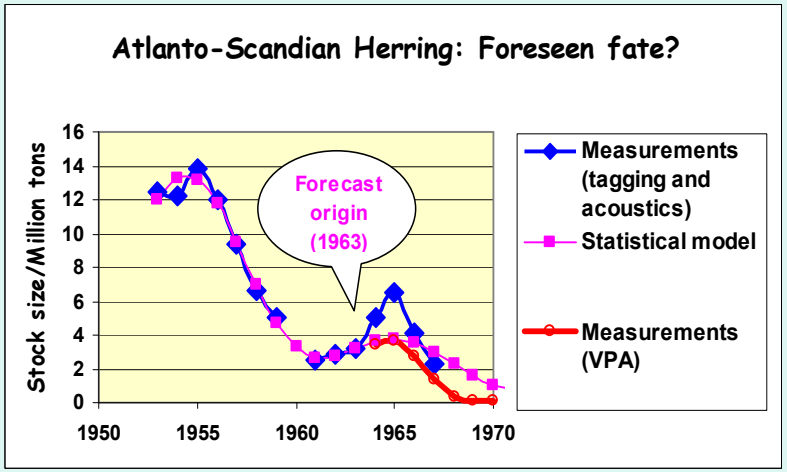
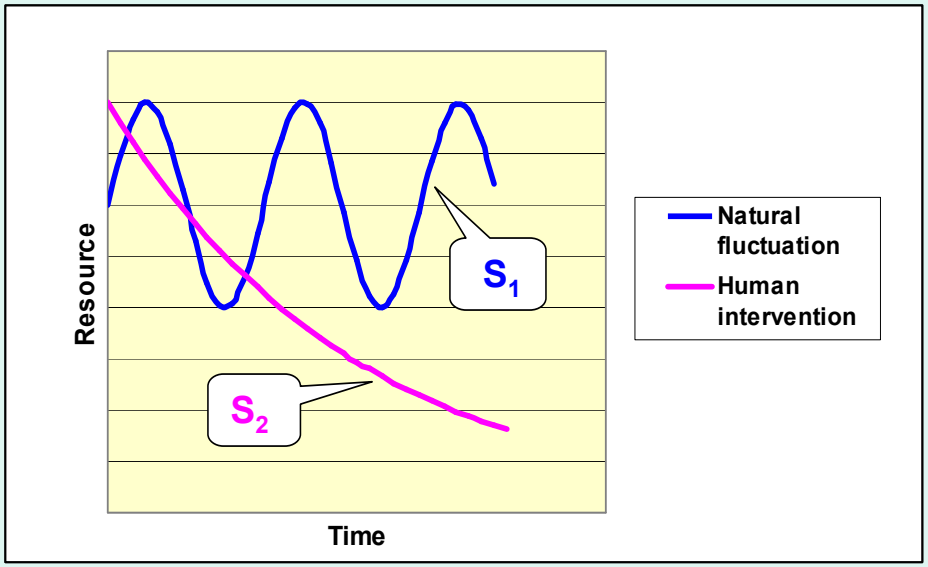


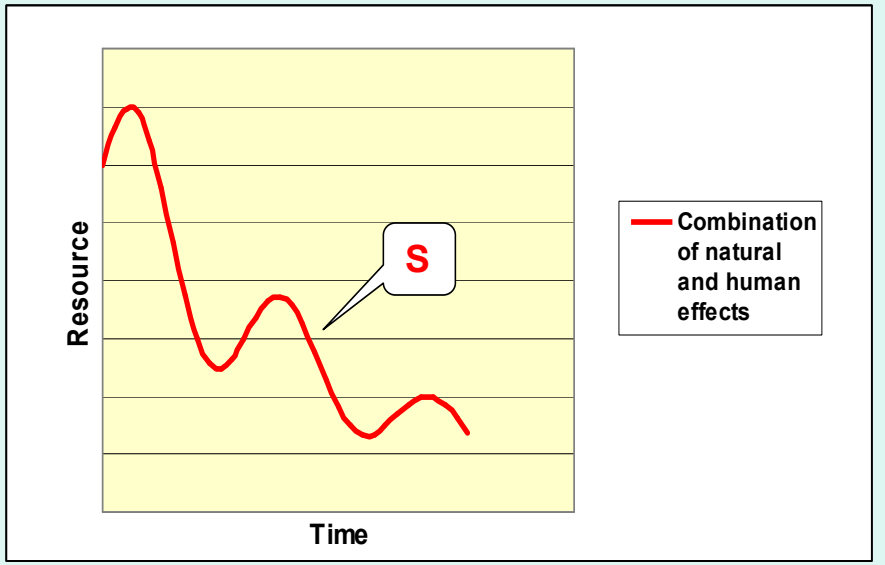


- *Herring in the ocean between Iceland and Norway was one of the largest fish stocks in the world until the fishery crashed in the late 1960s. The catch in 1971 was only 20 thousand metric tons in contrast with the record of 2 million tons in 1966 and the spawning stock declined from more than 10 million tons to 10 thousand tons in 20 years. After nearly 25 years of almost no fishing the stock finally recovered.*
- *The poster describes graphically statistics of stock measurements 1953-1963 and calculations according to the time series model* $S=Aexp(Bt)[1+Csin(Dt)]$ *where S is stock size and t time. After estimating the parameters statistically, the model is extrapolated, showing amazing similarities to the actual development – despite no biological assumptions. In retrospect one can speculate about an answer to the hypothetical question:*
  Could a mathematician have convinced the fishing community in the open access environment of that time to accept quotas on catch or effort already in 1964 to preserve this vital resource and prevent its drastic collapse?
- *The data in the first graph were available already in 1964 from tagging experiments and acoustic measurements supplemented by underwater photography and the model was tested in Excel Solver until that point in time.*
- *In the second graph the predicted stock development is compared to continued measurements of the same kind and more accurate stock assessment by virtual population analysis (VPA) – not possible until later when the collapse was a fact. The least-squares fit is even closer to the very abrupt VPA results.*

Reference: Sigurdsson, T. (2006) Could a mathematics student have prevented the collapse of the Atlanto-Scandian Herring? *Teaching Mathematics and its Applications, Volume 25, No 1, 43-50.*

Model Specification





Trigonometric function: $S_1 = 1+Csin(Dt)$

Product function:

$S=Aexp(Bt)[1+Csin(Dt)]$

Exponential function: $S_2 = Aexp(Bt)$

Computational Results

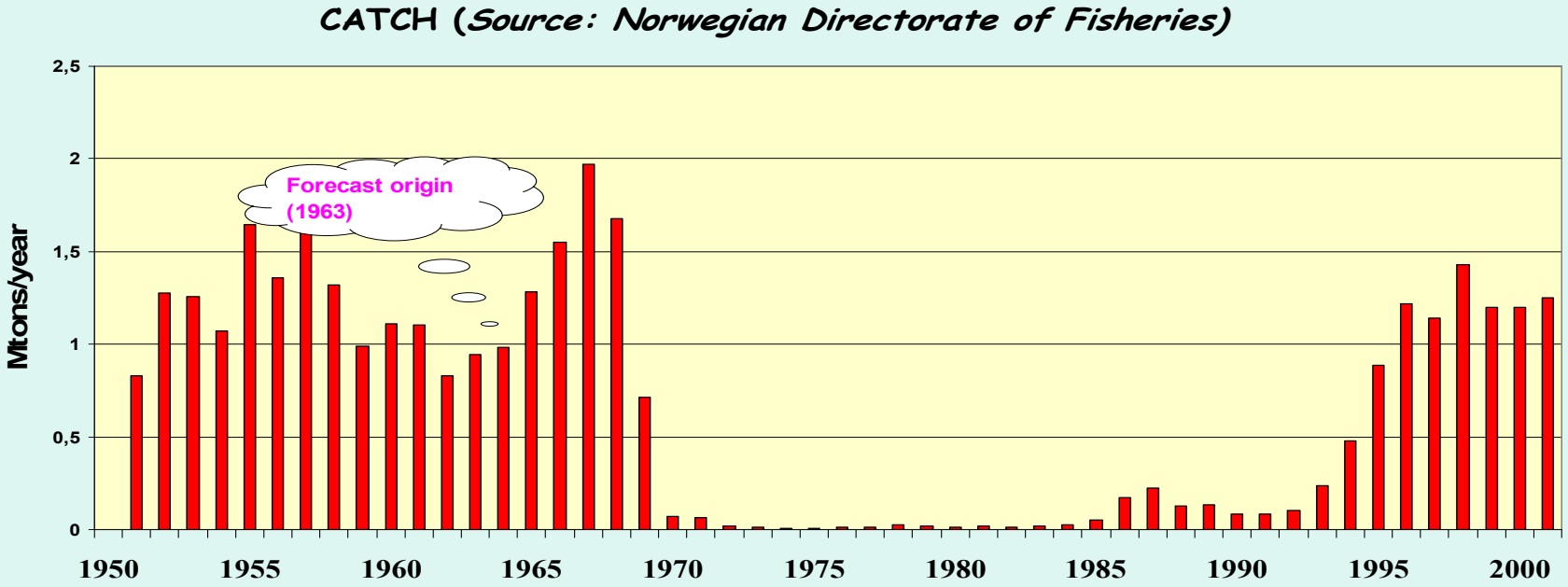
- ***Statistical method:*** Minimize $\sum(\Delta S)^2 = \sum(S_{measured} - S_{model})^2$

- ***Estimated model:*** $S = 12,03 \cdot e^{-0,120t}\{1 + 0,421 \cdot \sin(0,603\,t)\}$ Million tons

- ***Solver output:***

Year	t	S Measured	S Model	(ΔS)^2
1953	0	12,46	12,03	0,1840
1954	1	12,19	13,22	1,0665
1955	2	13,86	13,18	0,4551
1956	3	12,00	11,82	0,0310
1957	4	9,39	9,53	0,0174
1958	5	6,60	6,95	0,1170
1959	6	5,02	4,72	0,0920
1960	7	missing	3,26	
1961	8	2,50	2,68	0,0303
1962	9	2,85	2,79	0,0037
1963	10	3,25	3,24	0,0000
Minimized Residual Sum of Squares				**1,997**

Historical Background



- *Fishing for herring has a long history in northern Europe. For centuries this fish was a staple food and commercial product with a widespread distribution system including quality control. The traditional fishing grounds were in the Baltic, the North Sea, around Iceland and along the shores of Scandinavia and Russia to the White Sea, finally extending far into the high seas of the North-Atlantic Ocean. The herring fishery has always been characterized by fluctuations; sometimes abundant, sometimes scarce.*

- *After 1950 the fishery developed rapidly because of a new technology: sonar, power block, larger purse seine nets and bigger boats. As a result all major herring stocks in the Northeast-Atlantic collapsed in the late 1960s or early 1970s. The most dramatic decline was that of the Atlanto-Scandian stock (mostly Norwegian spring spawners) from millions of tons to the border of extinction in a decade. Economic opportunism, environmental effects and political mismanagement were also contributing factors.*

- *The collapse surprised both fishermen and scientists because catches stayed high almost until the very end. This paradoxical fact can be explained by failed recruitment and the shoaling behavior of the species. The question in this poster, however, is whether the collapse was mathematically predictable – even without knowing the biological mechanism.*