The Decline in World Wide Oceanic Fishing Harvests: Lotka-Volterra and Related Dynamics

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Chaos Network is now defunct.
Although it is common for fisheries managers to consider the case of each species individually, a certain amount of collective or aggregated analysis is required to understand some of the emerging properties of the oceanic ecosystems (Sugihara et al., 1994). For instance, the sharp decline in the Peruvian anchovy was met with a sudden increase in the sardine; the anchovy population made a sharp recovery eventually. The cod in the Newfoundland fishery, however, might not have a high chance of return as the ecosystem vacated by the cod has been filled by migrations of dogfish (Weber, 1994).

**Method**

The analytic approach of the present study was, therefore, focussed on the harvested biomass of the 16 major oceanic basins without regard to the specific species involved. Data were the peak catch levels of each basin (expressed in millions of tons), the catch level for 1992, and the number of years that elapsed between the peak and 1992. Data were reported in Weber (1994). (Note: although the world peak was 1989, the separate basins varied in their peak catch years.)

The data were analyzed using the method of hierarchical structural nonlinear regression equations (Guastello, 1995). Because there unequal time intervals in the original data, the variants with time as a variable were used. There were three models were tested. The first was the 1-simple chaotic process:

\[(1) z_2 = e^{(\theta_1z_1 + \theta_2)}\]

where \(z\) was the harvest level corrected for location and scale. The second model tested for the presence of a bifurcation effect where the bifurcation variable itself was not known:

\[(2) z_2 = \theta_1z_1e^{(\theta_2z_1 + \theta_3)}\]

The third model tested for time itself as a bifurcation variable:

\[(3) z_2 = \theta_1z_1^t e^{(\theta_2z_1)} + \theta_3\]

A comparison linear test was automatically built into these analyses with the test on the exponential regression weights.

**Results**

Parameter estimate, \(R^2\) coefficients and dimensionality calculations are shown in Table 1. Lyapunov dimensionality (\(D_l\)) is calculated as \(e^D\) in Equation 1. In Equations 2 and 3, \(D_l\) is \(e^{D} + 1\). All regression weights, except \(\theta_2\) for Equation 2 were significant.
Because of its low degree of fit, Equation 1, the simple chaotic model, was ruled out as an explanation of the data. Equation 2 showed that there was a simple linear decline in fishing harvests from the peak to 1992. Because its regression weight in the exponent was zero, its dimensionality was 1.00. It had the highest degree of fit of the three models tested. Figure 2 shows an iteration plot of Equation 2 for different initial conditions. The outcome was beguilingly linear; each successive annual catch is expected to be only 92% of the catch for the previous year. Eventually an asymptotic minimum would be reached.

Equation 3 also showed a high degree of fit, although it was not the best of the three. It was interpreted nonetheless because it illustrated the Figure 1. Projections based on Equation 2, model with bifurcation effect unknown and a linear outcome.

The model with time as bifurcation term, however, illustrated both the Lotka-Volterra function at the expected level of dimensionality. It also showed the stochasticity that contemporary researchers also identified through different numerical means and with other data sets. Its projections, however, were from the point of view of the fish; their population dynamics do not anticipate further adaptive responses from the fishers. Rather, if the fish populations were allowed to restore themselves, they would be back in full force. Of course, their populations would not explode as the end of Figure 2 suggests; there would be a limit to the carrying capacities of their environments that was not built into the model.

On the other hand, Figure 2 shows results for total fish quantity. It does not presume that the same species that disappeared will be the ones to recover. For all we know, the recovery would take the form of an abundance of carp and dogfish, rather than orange roughy and cod.

Finally, Figure 2 suggests that the catastrophic decline in harvests should be occurring right about now. Again, adaptive responses by fishers are to dredge deeper than before and to identify new species that were once considered junk. It is probable that these maneuvers would just forestall the inevitable, as depicted in Figure 1.

**Discussion**

The results of the analysis showed that it was possible to extract more than one viable and theoretically expected relationship from the data. The model with the better fit illustrated the simple harvest-decay function. It essentially meant that the international fishers would fish the oceans to exhaustion, all things being equal, and the prognosis would be that the exhaustion was permanent. This model tells the story from the point of view of the fishers, what they would capture, and how long the harvests could be maintained.

![Figure 2. Projections on worldwide fishing harvests based on Equation 3, and showing essentially a Lotka-Volterra function.](image)

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**References**
