

*The Effects of Endangered Species Rarity Value on Endangered Species Trade: A Focus on the Anthropogenic Allee Effect in Caspian Sturgeon (Acipenseriformes) from 1980 to 2001.*

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## **Abstract**

One of the most valuable aquatic species is Caspian Sea sturgeon whose caviar has held a luxury value for centuries. The Caspian Sea produced over 90% of the world's caviar and has seen a dramatic decline in sturgeon populations within the past twenty years due to overfishing and other anthropogenic causes (Mojaver, 2009). The topic of interest in this study is observing the potential presence of an Anthropogenic Allee Effect (AAE) that is based on the value of rarity of Caspian sturgeons. While humans cannot cause a natural Allee effect, they are able to push species into population ranges that can express the species' natural Allee effect (Stephens and Sutherland, 1999). Humans can however introduce an AAE in rare species due to the value of the species' rarity and demand related to that rare species. To understand the development of the AAE in Caspian sturgeon populations, databases including global and local fish catch count data were obtained and sorted focusing on sturgeon catch counts in the Caspian Sea region spanning from 1980 to 2001. The associated prices of three rare Caspian sturgeon species were obtained from the Convention on International Trade of Endangered Species (CITES) and International Union for Conservation of Nature (IUCN) lists from 1980 to 2001.

It was observed that as the overall sturgeon catch count in the Caspian Sea declined, the prices of three CITES and IUCN listed Caspian sturgeons increased dramatically from 1980 to 2001 with sharper increases occurring after 1996, when sturgeons were put on to the CITES Red List. A direct correlation between the species rarity (as indicated by status on CITES and IUCN lists) and increased prices was seen (Kendall concordance test,  $\tau = -0.34$  and  $p < 0.0001$ ). This data suggests strong evidence for a human induced AAE in Caspian sturgeons from 1980 to 2001.

## Introduction

The overexploitation of living species is considered a major threat to biodiversity, however theories predict that economic exploitation usually precedes the extinction of a species (Mojaver, 2009). If a living species' rarity makes them more valuable, their overexploitation can remain to be a profitable endeavor rendering a species even more rare and driving them to extinction, as seen with the Caspian sturgeon populations from 1980 to 2001 (Pikitch *et al.*, 2005). Human exploitation has been compared to the Allee effect: the correlation between a population's size or density and the population growth rate of the species. Populations suffering from Allee effects often show negative growth rates at low densities that further drive them to lower densities and ultimately to extinction. Human activities cannot create the Allee effect, though they can push species into density ranges where their natural Allee effect can be expressed (Stephens and Sutherland, 1999). Contrary to this claim, humans can induce an artificial Allee effect in rare species through the “paradox of value” called the Anthropogenic Allee Effect (AAE). In this study, the AAE is shown through Caspian sturgeon populations that are considered a highly valuable species.

The Caspian Sea produces 90% of the world's caviar, a highly coveted luxury good, despite a 90% decline in sturgeon numbers over the past twenty years (Pikitch *et al.* 2005). Due to large declines in their populations, all Caspian sturgeon species are listed under Convention on International Trade in Endangered Species (CITES) and the International Union for Conservation of Nature (IUCN) since 1996 (Raymakers, 2006). Despite this status, pressure on Caspian sturgeon species persists through a rising demand and illegal trade (Mojaver, 2009). The aim of this study is to assess whether the value of a species' rarity contributes to elevated costs in the luxury good associated with the species and the economic consequences that an AAE presents to caviar trade.

## Methods

Data of sturgeon catch counts was obtained from the CITES documents and FishStat Plus (Food and Agriculture Organization of the United Nations, 2014), a software database providing global and local databases of fish catch counts. The global database was utilized to obtain figures on Caspian region sturgeon catch counts from the following countries: The Islamic Republic of Iran, The Russian Federation, Kazakhstan, and Azerbaijan. Caviar prices for *H. huso*, *A. gueldenstaedtii*, and *A. stellatus*, were found from the CITES document releases from 1980 to 2001 (Raymakers, 2006).

In this analysis, the catch count of all Caspian sturgeon species and prices for the rarest Caspian sturgeon species (*H. huso*, *A. gueldenstaedtii*, and *A. stellatus*) were compared from 1980-2001, the most representative years of sturgeon catch decline and increase in caviar prices. Rarity was based on the associated CITES appendix that the species had been listed in.

Statistical analysis was done in the R software program. Correlation of determination values ( $R^2$ ) and p values were used to assess the overall decline of Caspian sturgeon and increase in prices of the three aforementioned sturgeon species. To understand the correlation between endangered species status and associated prices for respective species, a Kendall concordance test was performed. Sturgeons that were accounted for by the IUCN (critically endangered = 0 points, endangered = 1 point, vulnerable = 2 points, others = 3 points), and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES: Appendix 1 = 0 points, Appendix II = 1 points, Appendix III was not evaluated), and local protection (yes = 0 points; no = 1 point) were evaluated. The points were summed and the cumulative score was used to measure the rarity of the species; the lower the score, the rarer the species.

## Results

In accord with the presented hypothesis, the results found from this analysis suggest a presence of an AAE in Caspian sturgeon species from 1980 to 2001. It was found that there is an inverse

relationship between the overall Caspian sturgeon catch count compared to the prices of three highly sought after sturgeon species with significant values of  $p = 0.00032$ ,  $p = 0.0002$ , and  $p = 0.0002$  for (*H.huso*, *A. gueldenstaedtii*, and *A. stellatus*), respectively (Figure 1). The strong inverse correlation of prices to sturgeon catch count offers insight on the economic consequences of endangered species trade.

Economic consequences of endangered species trade were evaluated through a Kendall concordance test that tested the correlation between endangered species status and associated prices per species. The results show that the increase in caviar prices for three endangered Caspian sturgeon species is correlated with increased rarity (Kendall concordance test for nonparametric data  $\tau = -0.34$  and  $p < 0.0001$ ).

## Discussion

The results from this analysis suggests that the overfishing of a luxury item, Caspian sturgeons, has the potential to induce an AAE, though there are likely to be other reasons. The strong decline of the Caspian sturgeon population brought forth the 1996 listing of all Caspian sturgeon species under the Convention on International Trade in Endangered Species (CITES), a voluntary agreement made between governments to protect species threatened by trade and the most significant act that protects sturgeons (Raymakers, 2006). The CITES index has three appendices that categorize the severity of species' status: species threatened with extinction (Appendix I), and species of concern (Appendices II and III). *H. huso* is listed under Appendix I while *A. gueldenstaedtii*, and *A. stellatus* are listed under Appendix II (Pikitch *et al.*, 2005). Appendix I only allows trade for special circumstances and Appendix II allows for controlled trade of the species. The inverse correlation between overall decline of the Caspian sturgeon catch count and prices for three rare sturgeons from 1980-2001 (Figure 1) is in agreement with the hypothesis and shows the presence of caviar's rarity based value. Beluga caviar, *H. huso*, which had the highest price based on euro per kilogram, showed the sharpest declines in

population as compared to other Caspian sturgeons such as Osetra (*A. gueldenstaedtii*) and Sevruga (*A. stellatus*). All three sturgeon species displayed steep increases in cost after the 1996 CITES listing. Due to these enacted policies, the Islamic Republic of Iran and the Russian Federation halted all exports of caviar in 2001 and 2005, respectively.

The Kendall concordance test for non-parametric data showed the direct correlation of IUCN and CITES listings on the price of an endangered species. Caspian sturgeon species cited in Appendix I or II of CITES and receiving local protection from either the Iranian or Russian governments displayed significantly higher prices than sturgeon species currently not listed under CITES (*A. ruthenus*, *A. schrenckii*, and *A. baerii*) (Gessner *et al.*, 2002).

The economic value of caviar has lead to natural producing caviar countries such as Iran, Russia, Kazakhstan, and Azerbaijan to create fierce competition among them. During the 1980's, extensive efforts to promote farmed caviar were initiated as overall sturgeon counts continued to fall. Despite these efforts in Iran and Russia, the exports of wild caviar continued due to increased demand of wild black caviar and its importance in fueling the agriculture and aquaculture sectors of the Iranian and Russian economies (Mojaver, 2009). The legal and illegal trades of black caviar continue to be an extremely lucrative business despite endangered species listings. In 2000, the legal trade of black caviar from Russia produced an estimated \$40-100 million while the value of illegal Russian caviar exports has been estimated to be around \$250-400 million (Pikitch *et al.*, 2005). High quality beluga costs can rise to US\$5000.00 per kilogram with other wild and aquaculture caviar commands less costs and less of a presence in the legal caviar selling market.

Caspian sturgeon have been the main source of caviar for centuries, however, depletions in the populations of these sturgeon have made scientists, governments, and exporters more focused on other sturgeon species and close relatives such as paddlefish that are within the Acipenseriform order and within the Polyodontidae family (Raymakers, 2006). Recent focus on North American sturgeons and

paddlefish has shown great progress as many of these species have maintained their population counts and continue to be reproducing at normal rates (Pikitch *et al.*, 2005). The increasing knowledge of Acipenseriform biology has contributed greatly to the overall policy changes seen in the past ten years in regards to North American sturgeon and paddlefish. In relation to the conservational cause of the Caspian sturgeon, there is little that can be done to restore the extensive damage that overfishing and other anthropogenic factors have done to the Caspian Sea region.

Further research regarding economics and caviar trade can lead to studies on fishery management and sustainable production and maintenance of farmed fishes. There are potential opportunities to research the illegal trade of luxury goods and the corresponding effects on a particular country's economy. Examining of illegal trade could prove to be difficult since this is a hidden act and every occurrence of illegal trade is not recorded.

The results from this analysis display strong evidence for the presence of an Anthropogenic Allee Effect that is caused due to overfishing. Extensive fishing of Caspian sturgeons with little conservation protection and policy has lead to the depletion of Caspian sturgeon within the past twenty years. The depletion is not solely caused by the overfishing AAE as other AAEs not assessed in this study, such as pollution and tourism, have the potential to contribute to this issue as well. The lesson learned from the Caspian sturgeon conservation issue has helped aid in the research of fisheries and farming efforts to produce caviar that resembles wild caviar's taste and appearance while strictly monitoring the population counts of many wild North American and farmed sturgeons. More research on the rarity associated value of a particular species and the AAE can help not only in fishery research but in conservation biology and biodiversity management research as a whole.

## Acknowledgements

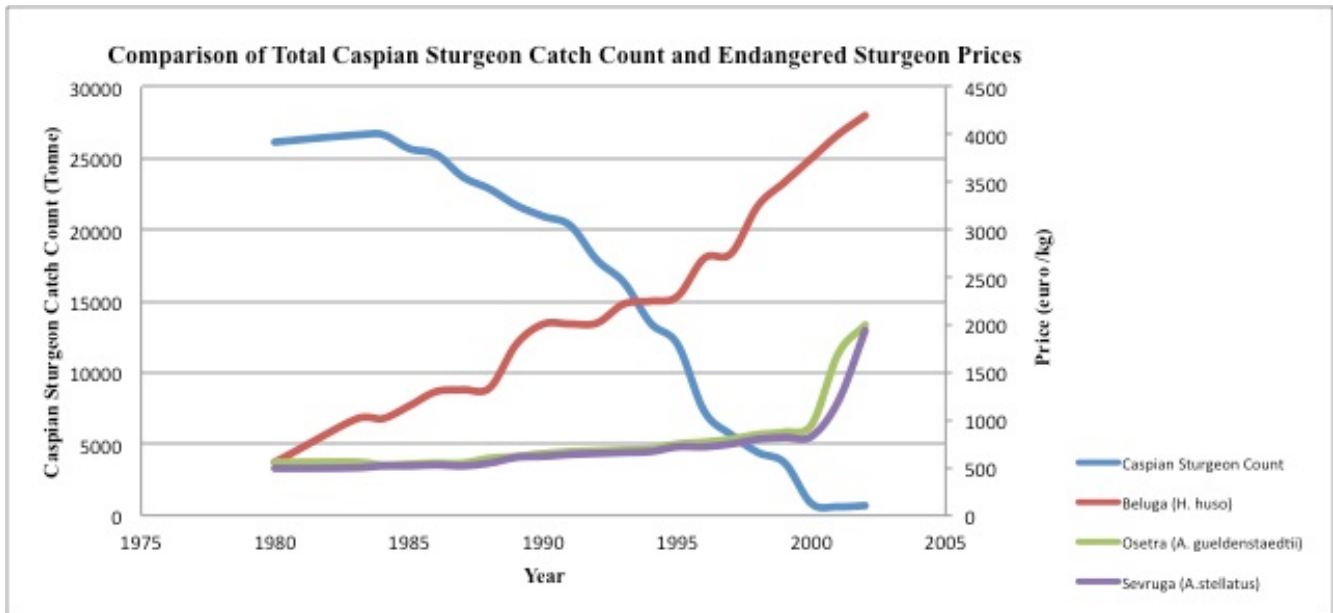
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## Figures



**Figure 1:** Increase in the prices of caviar from three endangered Caspian Sea sturgeon species as overall Caspian sturgeon stock depleted (1980-2001). Beluga (*H. huso*), Osetra (*A. gueldenstaedtii*), and Sevruga (*A. stellatus*) are the most sought after and have been listed in the CITES Red List since 1996. As seen in the graph, each sturgeon caviar price is inversely correlated to the size of the overall sturgeon count. For Beluga, Osetra, and Sevruga, respectively: ( $R^2=0.956$ ,  $p=0.00032$ ;  $R^2=0.554$ ,  $p=0.0002$ ;  $R^2=0.5542$ ,  $p=0.0002$ ).