**A Decline in the Abundance of European Silver Eels in Norway Has Led to an Increase in their Length and Weight**

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**Introduction**

The European eel (*Anguilla anguilla*) population has been in decline since the 1960s due to the reduction of freshwater habitats and the eel fishing industry. However, it is hypothesized that the population has been declining since the 1900s. In 2008, the European eel was officially recognized as an endangered species by the International Union for Conservation of Nature. In more recent times, suspects for the decline in European eels include climate change, pollution, overfishing, hydropower, and many others (Durif et al. 2020).

All European eels are spawned in the Sargasso Sea before they spread across Europe and neighboring countries. Monitoring stations across Europe have collected a stock of the eels by recruiting yellow eels (elvers or eels undergoing maturation in the yellow phase) to freshwater. Results are analyzed using time series. The decline in the population of eels is reported across all of Europe, but the northern stations experience it to a greater degree (1.9% vs 8.9%). One such station has collected data since the 1970s, the river Imsa in Norway. It is positioned where it records greater changes in population density than its southern neighbors, leaving the river Imsa as an important monitoring station. Its time series are essential to tracking total eel stock. Both the upstream ascending elvers and the downstream migrating silver eels are trapped, counted, and analyzed (Durif et al. 2020).

This paper aims to explore the changes in the physical characteristics of the European silver eel population coinciding with the declining abundance in Norway. Specifically, it is hypothesized there will be a significant increase in the eels' length and weight over time.

**Materials and Methods**

*Sampling Location*

Located in southwestern Norway, the river Imsa covers an area of 12,800 hectares (ha) (Figure 1). This includes 1,536 ha which belongs to lake surfaces through which the river flows. Traps were established in 1975 that catch both ascending and descending eels. They are located approximately 100 m upstream from the outlet and are checked twice per day (Durif et al. 2020).

Map

Description automatically generated

*Figure 1: Location of the river Imsa in southwestern Norway along with the wolf trap. Lakes are included in the bottom image* (Durif et al. 2020).

The wolf trap is responsible for capturing the descending silver eels and all downstream migrating fish. It functions year-round and in all water levels. For ascending elvers, a trap diverts them into a collecting chamber where their numbers and size sub-samples are recorded before they are released to continue upstream. Figures 2 and 3 visualize the number of ascending and descending eels recorded over the collecting years (Durif et al. 2020).

A picture containing histogram

Description automatically generated

*Figure 2: Annual counts of European eels in the river Imsa from 1975-2019. (a) the number of ascending elvers in the spring. (b) the number of downstream migrating silver eels in the fall from 1992-2019* (Durif et al. 2020).

Chart, line chart

Description automatically generated

*Figure 3: Annual counts of downstream migrating European silver eels in the river Imsa from 1975-2019* (Durif et al. 2020).

*Data Collection*

A total of 798 eels were caught and processed for various traits such as age, length, weight, and sex. The eels were gathered in 1982, 1986, 1991, 1992, 2012, 2014, 2015, and 2016. The size of the samples was 224, 102, 219, 117, 25, 25, 25, and 61 eels, respectively for each year. They were added to the total eel count for the year and sacrificed for the measurement of their characteristics. The length was measured in millimeters (mm) and the weight was measured in grams (g). There exists a gap in the data as the samples from 1982 to 1992 were gathered from historical data whereas the most recent data was sampled from downstream migrating eels in the river Imsa (Durif et al. 2020).

*R-Program Statistical Analysis*

The samples collected were further analyzed and formatted in R (version 2023.03.0+386). First, any columns not pertaining to weight and length were removed. Rows containing “NA” for length, weight, or both were also removed. This brought the total count to 794 eels. Data was analyzed across all 8 years. To determine if there was any significant change in the length and weight, a Bayesian regression analysis was performed on the data using the “brms” package. Both length and weight had separate Bayesian tests performed for the years. The eel datapoints for each year were plotted on separate graphs for length and weight. The model was fit to the graphs along with the datapoints.

**Results**

Looking at the length of eels over the years, there is an increase over time. Both the model fit and the datapoints show an increase from 1982. The only times the model decreases are once after 2012 and again after 2015 (Figure 4). The results are similar for the weight of eels. As the years increase, the weight increases in both the datapoints and the model. Similarly, there are only 2 decreases in which both are the same as the length graph (Figure 5). Both 1991 and 1992 appear to have more large size outliers than the other years on the graphs (Figures 4 and 5).



*Figure 4. Length of European eels by year with the length model fit to each year. The red dots and lines represent the model values. Each blue dot is a single eel sample.*



*Figure 5. Weight of European eels by year with the weight model fit to each year. The red dots and lines represent the model values. Each blue dot is a single eel sample.*

**Discussion**

Coinciding with the declining European eel population in Norway, the length and weight of the eels has increased since 1981. Both the graphs demonstrate an increase in the size of the eels along with the model. When comparing the datapoints in the 1980s and 1990s both groups appear to have larger weight and length outliers when compared to the 2010s likely due to the increased eel counts found in the earlier samples (Durif et al. 2020). There is a decrease in both length and weight from 2012 to 2014 and again from 2015 to 2016. The sample sizes for 2012, 2014, and 2015 are small (25) which could help contribute to bigger increases or decreases in the model and datapoints. The largest sample size in the 2010s was 2016 with 65.

Incidentally, there is a large gap of 20 years leaving a lot of room for change. While there is likely access to previous eel samples since they have been measured every year since the 1970s, Durif et al. (2020) elected to use only old and new data for their hypotheses. Their data is used for the hypothesis of this paper. However, the graphs do not indicate a drastic change in the most recent data given the gap in years. The length and weight appear to increase almost at a constant rate except for the 2 decreases (Figures 4 and 5). Samples from each year missing might reveal very minimal, but present increases in length and weight over the years.

Because of the variety of habitats in which they mature, European eels can vary greatly in growth, fecundity, and time spent in the growth phase (yellow stage) (Durif et al. 2020). The main hypothesis for the increased size of European eels in a declining population is the competition for food. In a habitat with a low eel density, there is less competition for food and thus better conditions for optimal growth (Denis et al. 2022). The river Imsa is a good example of this with its decreasing stock over the years, but an increase in length and weight. Overall, further research is needed to determine the most prominent causes for the increase in length and weight as the European eel population continues to decline.

**References**

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