**A Decline in the Abundance of European Silver Eels in Norway Has Led to an Increase in their Median 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).

European eels are spawned in the Sargasso Sea where the larvae ride the gulf stream until they hit the continental shelf of European countries. There, the eels metamorphose into glass eels (elvers) in freshwater and coastal environments. When the elvers have grown and become silver eels, maturation is complete, and they are ready to spawn new offspring. They will travel back to the Sargasso Sea to achieve this feat (Durif et al. 2020).

Monitoring stations across Europe have collected a stock of the eels by recruiting elvers to freshwater. Results are analyzed using time series. A notable decline in stock become apparent in the 1980s with northern stations experiencing greater decreases. One such station has collected data since the 1970s, the river Imsa in Norway. There, 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 change in the eels' length and weight over time, whether it be an increase or a decrease.

**Materials and Methods**

*Sampling Location*

Located in southwestern Norway, the river Imsa covers an area of 12,800 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. 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) (Durif et al. 2020).

*R-Program Statistical Analysis*

The samples collected were further analyzed and formatted in R. 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. Next, the data were cut into decades, the 1980s, 1990s, and 2010s using the “tidyr” package. The eel counts for each were 326, 333, and 135, respectively. A boxplot was created using the “ggplot2” package. Separate boxes were created for length and weight for each decade. Decades were plotted on the x-axis and the units of measurement, either mm or g, were plotted on the y-axis.

To determine if there was any significant change in the median length and weight across the decades, a non-parametric Kruskal-Wallis test was performed on the data. If there was a significant difference in the medians, a Dunn’s multiple comparison test would determine which group was statistically significant (Denis et al. 2022). The assumptions of the Kruskal-Wallis test are as follows: it is assumed that the observations in the dataset are independent of one another, it is assumed that the distribution of the population is not necessarily normal and the variances are not necessarily equal, and it is assumed that the observations must be drawn from the population using random sampling (Lani 2009).

**Results**



*Figure 4: Boxplot comparing the length and weight of eels in the various decades. Length is light blue, and weight is pink.*

The boxplot reveals a minimal change in length and weight from the 1980s to the 1990s. However, the 2010s display both a greater median length and weight when compared to either of the other 2 decades. The median length was 610, 608, and 690 mm for each decade, respectively. The median weight was 385.5, 393, and 585 g each, respectively (Figure 4). The results of the non-parametric Kruskal-Wallis test between length and decade revealed a significant change in one or more medians across the decades (p < 0.001). Similarly, there was a significant change in the median weight (p < 0.001). The Dunn’s multiple comparison test determined the 2010s decade was statistically significant from both the 1980s and the 1990s in both median length and median weight (p < 0.001).

**Discussion**

Coinciding with the declining eel population in Norway, the median length and weight

significantly increased in the 2010s compared to the 1980s and 1990s. The boxplot revealed the increase and a non-parametric Kruskal-Wallis test and Dunn’s multiple comparison test confirmed the findings (Figure 4). Each returned a significant value (p < 0.001). The 1980s and 1990s appear to have more outliers when compared to the 2010s likely due to the increased eel counts in each decade (Durif et al. 2020).

All European eels are spawned in the Sargasso Sea before they spread across Europe and neighboring countries. 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). The decline in the population of eels is reported across all of Europe, but the northern regions experience it to a greater degree (1.9% vs 8.9%). In turn, Norway 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 (Durif et al. 2020).

The main hypothesis for the growth 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 median length and weight. Overall, further research is needed to determine the most prominent causes for the change in length and weight as the eel population continues to decline.

**References**

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