



UNIVERSITY OF  
GOTHENBURG

DEPARTMENT OF MARINE SCIENCES

# GUT CONTENT ANALYSIS OF FISH SPECIES IN GÖTA ÄLV

A study investigating the food web within Göta älv in  
relation to the reintroduced sturgeon



*Illustrated by Duane Raver*

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## ABSTRACT

Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) has been extinct in the river Göta älv for approximately one hundred years, marking the loss of a historically significant species. However, ongoing reintroduction efforts have made it possible for the species to once again occupy the ecosystem. To fully understand how the Atlantic sturgeons may integrate and interfere with other species following its reintroduction, it is important to possess a deep understanding of the dynamics of the already existing ecosystem within Göta älv.

This study aimed to further elucidate the structure of the Göta älv ecosystem by constructing a food web and identifying trophic levels within Göta älv. A fishing using fyke nets was performed at four different locations, and the gut content of the caught fish species were analysed. Through several computational analyses and comparisons to already existing literature, a food web could be determined, allowing for predictions on how the Atlantic sturgeon may come to integrate with it.

The results revealed the diet of seven fish species. With most species exhibiting a strong dietary preference and, some species showing overlapping diets, indicating potential competition. By comparing the gut content with the invertebrate fauna, it was further suggested that the fish in Göta älv may also feed selectively. Reintroduced sturgeon will most likely feed on annelid worms, competing with species such as European flounder and round goby, which were revealed to almost exclusively feed on Polychaetas. However, the Atlantic sturgeon may also feed on Chironomidae as these were indicated as an unutilised food source within Göta älv.

## SAMMANFATTNING

Atlantstör är en fiskart som tidigare funnits i Göta älv men som varit utdöd i över hundra år. Just nu pågår ett arbete med att plantera ut nya störrar, med mål att återigen ha ett livskraftigt bestånd av stör i älven. För att utsättningen ska fungera så bra som möjligt är det viktigt att förstå hur dynamiken mellan de olika arterna i älven ser ut, Den kunskapen kan, sedan användas för att uppskatta vad störrarna kan tänkas äta, vilka arter de kommer konkurrera med, samt vilka arter som kan komma att äta stören.

I det här projektet undersöktes detta genom att genomföra ett fiske med ryssjor på fyra olika platser i älven. Jag undersökte sedan maginnehållet på de fångade fiskarterna för att ta reda på vad de kan tänkas äta. Ytterligare, jämfördes detta med existerande information från tidigare forskning över vilka ryggradslösa djur som finns på botten, samt information som beskriver vad störrar äter i en annan älv.

Undersökning visade att de fångade fiskarterna oftast hade en specifik favoritföda, där några fiskarter hade en mer likvärdig diet än andra. Det visade sig även att vissa fiskarter specifikt valde en typ av föda över en annan. De utplanterade störrarna kommer mest sannolikt att äta olika typer av maskar, något som även skrubbskäddor och svartmunnad smörbult äter mycket utav, vilket gör dem till potentiella konkurrenter. Det finns också potential för stören att äta fjädermygslarver då undersökningen visade att ingen annan fiskart verkar äta det, samtidigt som det finns mycket av dem i botten.

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# 1. BACKGROUND

## 1. 1 Biology of the Atlantic Sturgeon

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The Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) is one of 27 existing sturgeon species worldwide (Havs- och vattenmyndigheten, 2016). Its native range includes the eastern coast of North America and parts of northern Europe (Hilton & Fox, 2022). The Atlantic sturgeon is an anadromous species, implying that it hatches in freshwater rivers, where it also spends the early stages of its life. It later migrates to the ocean, where it grows to adulthood. Once sexually mature, it returns to the same freshwater habitat where it was born to spawn (Havs- och vattenmyndigheten, 2016).

Atlantic sturgeons display strong homing behaviour, meaning they naturally return to their natal rivers to reproduce. This behaviour however results in limited gene flow between populations (Grunwald et al., 2008). Spawning typically occurs during the summer in large rivers with hard, well-oxygenated substrates. During their spawning migration, adult sturgeons refrain from feeding, an adaptation most likely linked to them avoiding consuming their offsprings. After hatching, juveniles remain in freshwater, occupying deeper areas with softer substrates while foraging for food (Gessner, 2019). Atlantic sturgeons are bottom-dwelling feeders, consuming a diet that mainly includes invertebrates, worms, molluscs, and small fish (Guilbard et al., 2007). Juveniles (1+) within the Nanticoke River have a recorded diet dominated by Annelid worms (61%) followed by Aquatic isopods (23%), Amphipods (10%), Chironomid larvae (1.6%) and Mysids (1.5%) (Secor et al., 2000).

As juveniles grow they become more tolerant of saline conditions and gradually migrate toward the ocean, usually completing this transition within their first six years (Smith, 1985). Adult Atlantic sturgeons are known to travel over 3,000 km from their home rivers (Gessner, 2019).

They reach sexual maturity at a minimum age of 10 years. Males typically spawn annually, while females spawn approximately every four years. They are long-lived, with a potential lifespan of up to 100 years, and can reach sizes of up to 4.3 meters in length and 370 kilograms in weight (Havs- och vattenmyndigheten, 2016). However, the sturgeon's slow growth rate, infrequent spawning, and late sexual maturity have made the species particularly vulnerable to overexploitation (Smith, 1985).

## 1.2 History of the Atlantic Sturgeon

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Atlantic sturgeons have historically been a significant item of commerce with fishing for them dating back hundreds of years. Overfishing and habitat loss has however resulted in the decline of Atlantic sturgeon with only a fraction of the original population currently existing (Hilton & Fox, 2022). The Atlantic sturgeon is today well protected from several authorities, such as Helcom, Oskar and Cites to prevent further decrease within the population. In Sweden the species has been declared national extinct with the last breeding population living in the end of 1800s within Göta älv. A Distinction strongly linked to overfishing and expansion of hydro dams. Today several projects worldwide are actively working to reintroduce or reinforce Atlantic sturgeon populations (Havs- och vattenmyndigheten, 2016).

## 1.3 Reintroduction of Endangered Species

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Reintroduction of endangered species can potentially have a crucial role restoring balance to disturbed ecosystems, preserving biodiversity, and counteract human impacts on the nature. A reintroduced species may play an ecological key role to an ecosystem allowing it to function naturally, in turn benefiting both itself and other species. Additionally, reintroductions can hold cultural significance for humans (Corlett, 2016).

Reintroductions of sturgeons primarily involve stocking and subsequently releasing juvenile sturgeons into suitable habitats. A method with successful results in rivers like Elbe and Rhine (Friedrich et al., 2019). One of these projects currently occurs within Göta älv, where stocked Atlantic sturgeon juveniles are released within the river. The first sturgeons were released in June 2024, with additional releases planned for the future. The goal of the project is to once again have a self-sustaining spawning population of Atlantic sturgeon in Göta älv (<https://storensaterkomst.se/>).

The introduced sturgeons in Göta älv will not only benefit biodiversity but also have the potential to contribute positively to the ecosystem. Being a relatively big fish species, the Atlantic sturgeons may act as a host to organisms with a parasitic lifestyle, such as sea lampreys. As a bottom-dwelling fish, the Atlantic sturgeon will also stir up the bottom substrate, oxygenating the riverbed and favouring a wider range of organisms (Sportfiskarna, 2024). It is also known that sturgeons in general have the potential to feed on invasive species such as round goby (Bruestle et al., 2019). However, the reintroduction of sturgeons will also alter the dynamics of the food web. It may affect competition within the fish community while also

influencing the conditions for the organisms it preys on and those that prey on it. These changes could impact population structures, species interactions, and overall ecosystem balance (Brevé et al., 2022).

## 1.4 Göta älv

Göta älv is Sweden's largest river in terms of mean water flow, with a drainage area covering approximately one-tenth of the country's surface. It spans between lake Värnen and Kattegat near Gothenburg. In Kungälv, the river splits into two river branches with the northern branch being called Nodre älv while the southern branch retains its original name, Göta älv. Being one of Sweden's most significant freshwater systems, Göta älv plays a central role in human interests, including hydro dams, water reserves, and water transportations.

However, Göta älv also host a complex ecosystem. Within Göta älv 37 freshwater fish species are found, making Göta älv one of the bodies of water containing the most fish species in Sweden, each species with its own ecological niche (Table 1). The high abundance of fish species is partly explained by Göta älv's connection with the sea, allowing anadromous fish species to migrate up the river. Additionally, the river creates a brackish water estuary in connection to the river mouth allowing fresh and saltwater species to interact (Göta älvs vattenvårdsförbund, 2016).

Previous test fishing findings provides evidence that the most abundant fish species in Göta älv are perch, pike, roach, bream, bleak, ruffe, ide and common dace (Carlstein & Sundbaum, 2014). Additionally, species like European flounder, European eel, European plaice, round goby, burbot, brown trout, Atlantic salmon and sea lampreys have also been recorded in the river. With the round goby, European flounder and European plaice primarily found near the river mouth, where freshwater and marine environments interact (Carlstein & Sundbaum, 2014; Green, 2020; Jacobsen & Johansson, 1999). In Sweden, burbot, European eel, and sea lampreys are all included on the national red list, with both European eel and sea lampreys classified as critically endangered. Conversely the round goby is recognized as a highly invasive species (SLU, n.d.).

**Table 1: A description of Some of the most abundant fish species within Göta älv as well as their typical ecological niches and diets (SLU, n.d.).**

Species	Ecology	Diet
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<b>Pike,</b> <i>Esox lucius</i>	Top predator within freshwater ecosystems, often ambushing pray in cover of vegetation.	Juveniles consume small crustaceans, insect larvae and fish fry. Successively adjusting to a fish diet as they grow to adulthood.
<b>Perch,</b> <i>Perca fluviatilis</i>	Opportunistic predator, commonly living in shoals, often hunting in the pelagic.	Adults have a fish dominant diet, while juveniles eat crustaceans, insect larvae and zooplankton.
<b>Roach,</b> <i>Rutilus rutilus</i>	An omnivore, able to adjust its diet depending on competing species. It is an important food source for pike and perch.	Invertebrates, zooplankton and plant debris.
<b>Bream,</b> <i>Abramis brama</i>	A bottom-dwelling fish species often found in shoals. They search their diet in soft sediment bottoms.	Benthic invertebrates and organic material.
<b>Bleak,</b> <i>Alburnus alburnus</i>	Often found in big pelagic shoals, feeding from the surface and the pelagic.	Insects and zooplankton.
<b>Ruffe,</b> <i>Gymnocephalus cernua</i>	Generally, lives and feeds near the bottom.	Small invertebrates and fish roe.
<b>Ide,</b> <i>Leuciscus idus</i>	An omnivore generally, search its food close to the bottom.	The main diet consists of benthic invertebrates and plant debris, larger individuals do however also include fish.
<b>Common Dace,</b> <i>Leuciscus leuciscus</i>	Living in small shoals, partly feeding from the surface.	Varius invertebrates.
<b>European Eel,</b> <i>Anguilla anguilla</i>	Catadromous fish species (migrate from freshwater to the sea to spawn), that are nocturnal, spending the daytime hiding.	Carnivores, with a diet mainly consisting small fish, mollusks and crustaceans.

<b>European Flounder,</b> <i>Platichthys flesus</i>	A marine flatfish, that is able to tolerate freshwater and therefore occasionally found in freshwater-systems connected to sea. It spends its life at the bottom.	Mainly benthic invertebrates.
<b>European Plaice,</b> <i>Pleuronectes platessa</i>	A marine flatfish, that is able to tolerate freshwater and therefore occasionally found in freshwater-systems connected to sea. It spends its life at the bottom.	Mainly benthic invertebrates. Bigger individuals also include smaller fish species.
<b>Round Goby,</b> <i>Neogobius melanostomus</i>	An euryhaline fish species that is Invasive in Sweden, it lives both in fresh and saline water relatively shallow.	Its main diet consists of molluscs, but they also consume smaller fish and crustaceans
<b>Burbot,</b> <i>Lota lota</i>	A predatory fish that prefers cold water, often residing close to the bottom.	Adults main diet consists of fish and crustaceans, while juveniles consume smaller invertebrates.
<b>Brown Trout,</b> <i>Salmo trutta</i>	It is a predator that may have an anadromous lifecycle but can also complete its entire life within freshwater.	Juveniles primarily feed on crustaceans, gastropods, and various insects. Adults have a fish dominant diet.
<b>Atlantic Salmon,</b> <i>Salmo salar</i>	Has a predatory lifestyle with an anadromous lifecycle. Adults, therefore, only return to freshwater to spawn. With exception for certain populations that complete their entire life within freshwater.	Juveniles consume various invertebrates; they then transition to fish diet as they grow to adulthood.
<b>Sea Lamprey,</b> <i>Petromyzon marinus</i>	A parasitic fish with an anadromous lifecycle.	Mainly bigger fish species, but also marine mammals.

It feeds by attaching itself to its  
prey.

Although previous investigation of the benthic invertebrate fauna within Göta älv is relatively limited a previous bachelor thesis suggested that it consists of Oligochaeta, Nematode, Trichoptera, Gammaridae, Chironomidae, Gastropoda, Bivalvia, Turbellaria, Coleoptera and Hirudinea. With the most abundant groups being Oligochaeta and Chironomidae (Gilså, 2024).

## 1.5 Food Web

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The interaction between species within Göta älv are still rather uncharted, particularly regarding the trophic relationships among fish species and their specific diets. To gain a deeper understanding of the ecosystem and its structure it is crucial to investigate the food web dynamics, subsequently quantifying the trophic levels.

By examining the gut content of the different fish species, a determination of their diet can be made which will give a valuable insight of the different species roles and the overall ecosystem dynamics (Baker et al., 2014). It will also provide valuable information to the ongoing sturgeon project.

## 1.6 Aim

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The objective of this investigation is to establish a deeper understanding of the food web and the trophic levels within Göta älv, more specifically the interaction between the existing fish species and their diet. This will be achieved through a fishing using fyke nets followed by analysis of gut contents from the captured specimens. The resulting data will provide valuable insights into the structure and functioning of the river's ecosystem, unveiling the different fish species and their diet.

Furthermore, the dietary data will be compared with existing information on the benthic invertebrate fauna of Göta älv, as well as with literature describing the diet of juvenile Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). This will serve as a basis for assessing its dietary niche, but also to assess how the Atlantic sturgeon may integrate and interact with other fish species following its reintroduction.

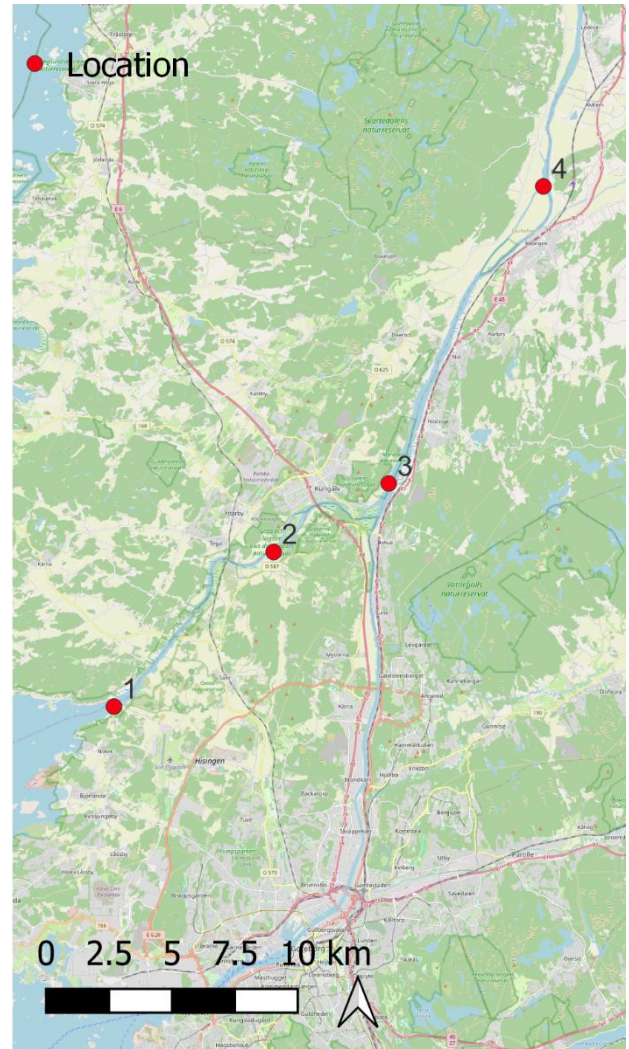
## 2. METHOD

### 2.1 Fishing

The fishing was conducted at four locations within the Göta älv between October 22–25, 2024. Two of the sites were located upstream of Kungälv, and two were situated within the Nordre älv branch (Figure 1).

Sampling was conducted using double-ended fyke nets, each consisting of two connected fykes with a 5-meter leader. The fykes is a 2.6-meter funnel section in turn consisting of three internal funnels. Mesh sizes ranged from 18 mm at the funnel throat to 11 mm at the cod end. Four fyke nets were deployed at each location for a period of 48 hours, at water depths ranging from 1 to 6 meters.

The total number of fish and species caught at each location was recorded. All fish, except for critically endangered species, were retained. Each retained individual was measured to the nearest millimetres and then frozen for subsequent analysis.



**Figure 1:** Map showing the fishing locations. Location 1: 57.793288, 11.837626, Location 2: 57.848139, 11.943995, Location 3: 57.872462, 12.020617, Location 4: 57.977569, 12.123583 (WGS84)

### 2.2 Gut Content Analysis

For gut content analysis, the digestive tract of each fish was removed and opened. Contents were analysed under a microscope and identified to the lowest possible taxonomic level. Any unidentifiable material was excluded from further analysis. Identified prey items were kept separate for each individual fish and grouped taxonomically. The contents were then counted, dried at 75°C for a minimum of 48 hours and subsequently weighed (accuracy of 0.001 g). The diets were determined in dry weight to eliminate fluids, as these do not reflect the weight of the diet components and could lead to inaccurate values. Dry weight is a more preferred approach

compared to the count of the different diet components as it better resembles the true diet proportion.

## 2.3 Statistical Analysis

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Diet composition was determined for each fish species. The dietary data were compared statistically between the species using a chi squared tests ( $\chi^2$ ).

To evaluate patterns in species composition between the sampling locations, as well as dietary variation among the different fish species, Principal Coordinates Analysis (PCoA) was performed using Bray–Curtis dissimilarity matrices. This allowed for visualization of the similarities and differences in both fish community structure and gut content composition across locations and species.

In addition, Shannon diversity index was calculated for each location to quantify species diversity, providing a comparative measure of ecological complexity among the sampling locations. Bootstrapping was performed with 1000 iterations.

The identified invertebrate gut content was compared with sediment samples of benthic invertebrate fauna collected from the Göta älv (Gilså, 2024) as part of a bachelor project. Additionally, dietary data were compared to published gut content data of juvenile Atlantic sturgeon (*Acipenser oxyrinchus*) from the Nanticoke River (Secor et al., 2000).

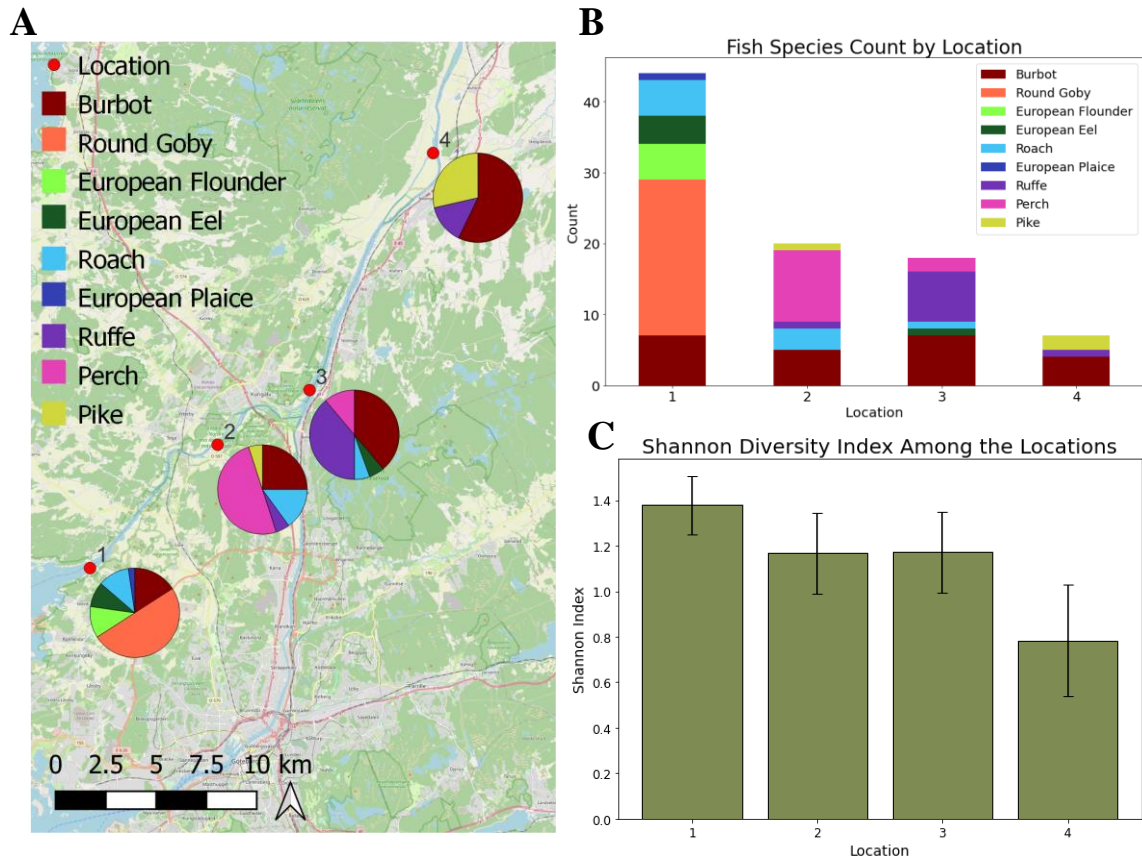
### 3. RESULTS

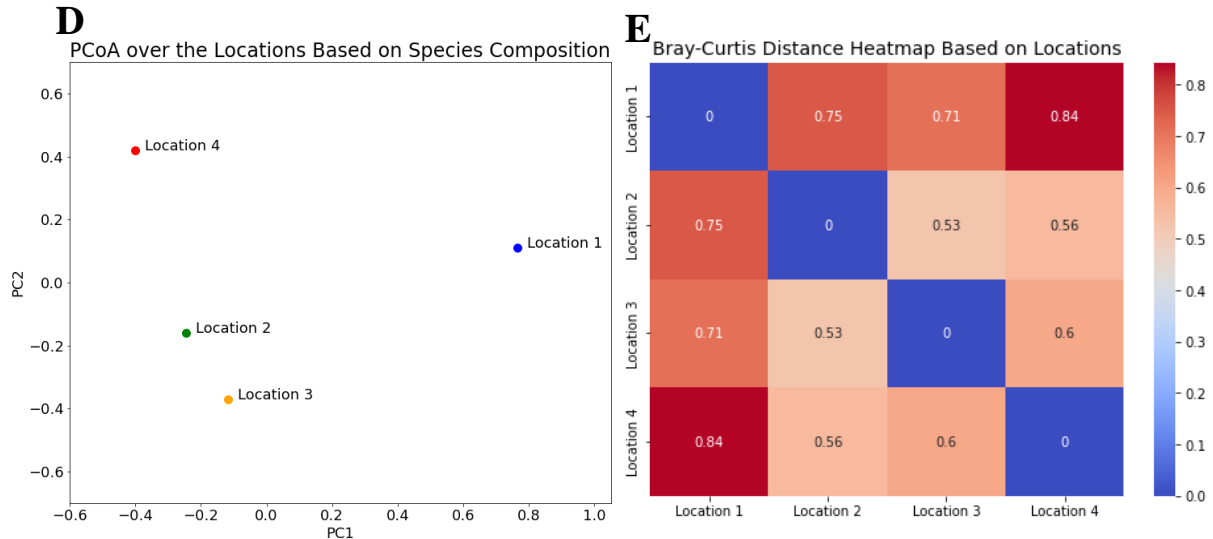
#### 3.1 Fish Species Composition at Each Location

The fishing resulted in a total of 89 fish and 9 different fish species (Figure 2B). In total 23 burbot, 22 round goby, 5 European flounder, 5 European eel, 9 roach, 1 European plaice, 9 ruffe, 12 perch, and 3 pike were caught across the four locations. The number of caught fish for each species varied between the locations with round goby, European flounder, and European plaice only being caught at location 1 (Figure 2A-B).

Shannon diversity index among the locations were (1.38) for location 1, (1.16) for location 2, (1.18) for location 3, and (0.79) for location 4 (Figure 2C).

The PCoA plot and Bay Curtis heatmap illustrates that location 1 and location 4 were the most distant in terms of fish species composition (Figure 2D-E). Location 2 and 3 were the most similar. Location 1 had at least a 71% difference in fish species composition compared to the other locations. A chi<sup>2</sup> test revealed a significant difference in species composition between the locations overall ( $p = 2.73954E-11$ ).





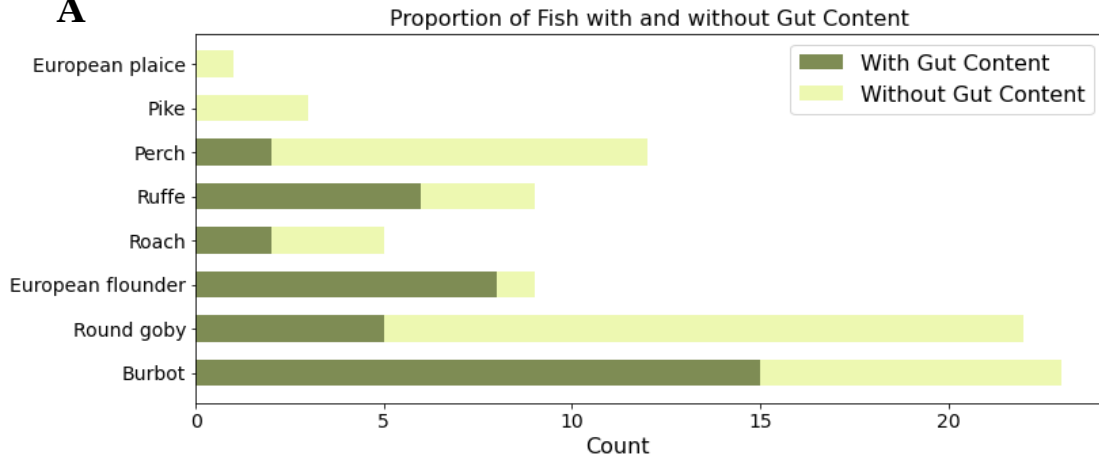
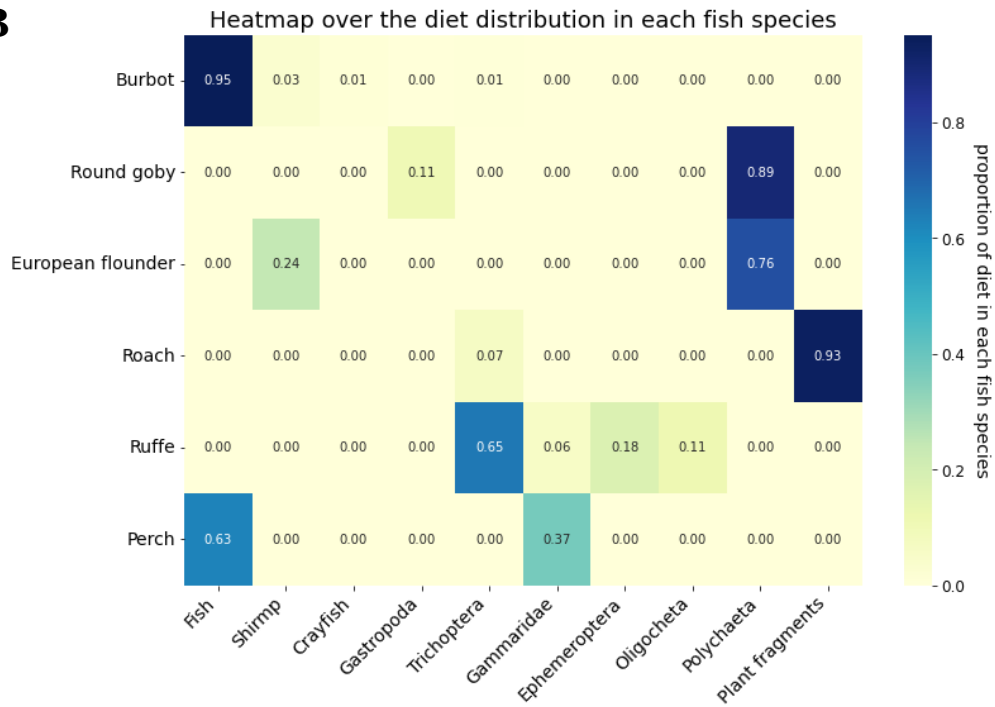
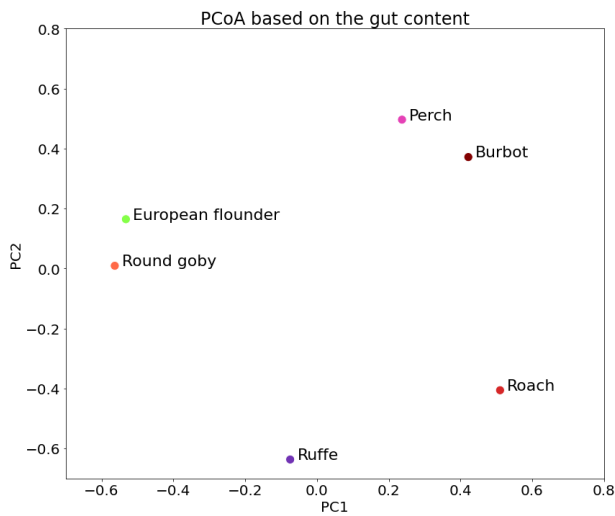
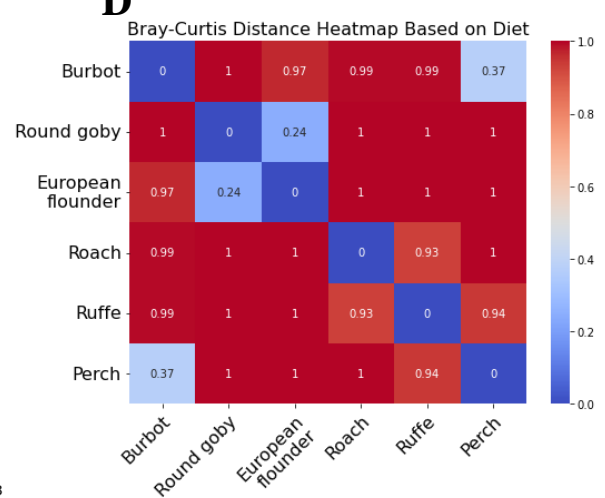
**Figure 2: Distribution of fish species at each location.** (A) A map displaying the distribution of fish species caught at each location with the different colours indicating the species. (B) A bar-plot illustrating the number of fish caught at each location. Each bar is colour coded showing the number of each species caught at each location. (C) Shannon diversity index among the locations. Shannon index mean calculated using bootstrapping of 1000 iterations. Error bars showing the standard error of the bootstrapped mean. (D) PCoA visualizing similarities among the locations based on the fish species composition in relation to each other. The plot uses the Bray-Curtis distances (E) A heatmap displaying the Bray-Curtis distance between the locations, 1 indicates a 100% difference while 0 indicates a 100% similarity in the fish species composition between the compared locations. Red in the colour gradient indicates a higher dissimilarity while blue indicates a higher similarity.

### 3.2 Dietary Composition in Fish Species

Approximately 45% of all fish had identifiable content within their guts (Figure 3A). Among the nine species, pike and European plaice had no identifiable gut content. Additionally, the European eels were excluded from the analysis as they were released because of their endangered status. The percentages of individuals from each species with identifiable gut contents were: burbot 65%, round goby 23%, ruffe 89%, European flounder 40%, roach 67%, and perch 17%.

The total dry weight of the identifiable gut content for each species were: burbot (25.3g), round goby (0.08g), European flounder (0.03g), roach (0.05), ruffe (0.48g), perch (0.08g).

The heatmap displays that the most dominant food preference for each species based on the dry weight of the gut content were: fish for burbot and perch, polychaeta for round goby and European flounder, plant fragments for roach, and Trichoptera for ruffe (Figure 3B) The PCoA plot and Bray-Curtis heatmap depicts that European flounder and round goby has similar diets (76% similarity) as well as burbot and perch (63% similarity) (Figure 3C-D). Roach and ruffe did not share more than 7% similarity in diet with any other species.

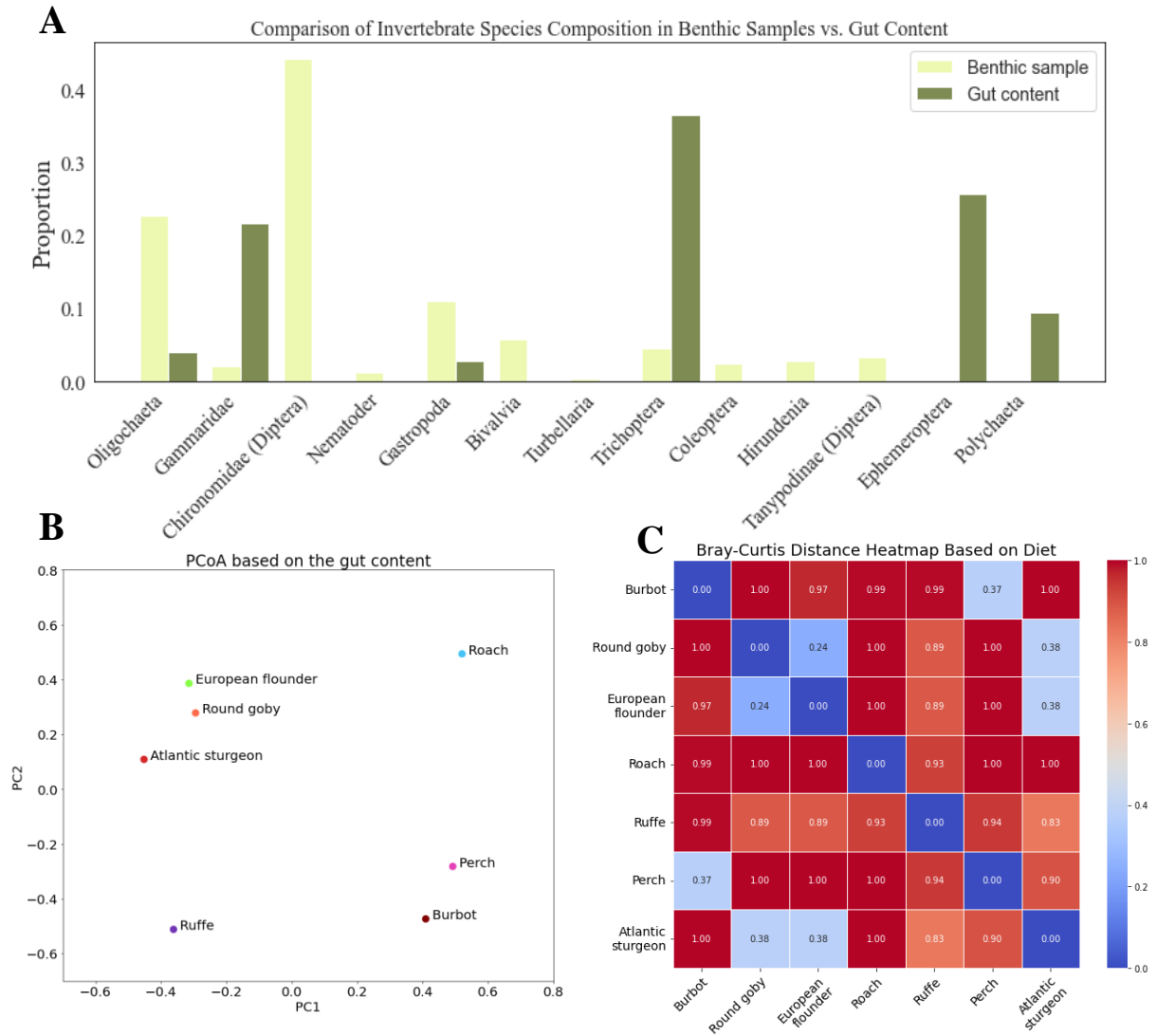
**A****B****C****D**

**Figure 3: Dietary Data from the caught fish species.** (A) A bar-plot displaying the number of fish with and without identifiable gut content from each species. (B) Heatmap exhibiting the proportion of dry weight in the identifiable gut content for each fish species. Y-axis displays the fish species; X-axis displays the different identifiable gut content components. (C) PCoA visualizing similarities among the fish species based on the gut content composition in relation to each other. The plot uses the Bray-Curtis distances. (D) A heatmap displaying the Bray-Curtis distance between the fish species based on their gut content, 1 indicates a 100% difference while 0 indicates a 100% similarity in the diet composition between the compared species. Red in the colour gradient represents a higher dissimilarity while blue represents a higher similarity.

### 3.3 Comparison to Previously Published Data

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The composition of invertebrates in frequency differed between the gut content and the benthic samples (Figure 4A). With Trichoptera being the most dominant type of invertebrate within the total gut content (ca 36%), compared to Chironomiade within the benthic sample (ca 44%). Juvenile Atlantic sturgeons from Nanticoke River had in comparison with the fish caught within Göta älv most similarity in diet with round goby (62% similarity) and European flounder (62% similarity), and no shared diet with roach or burbot (Figure 4B-C). The invertebrate composition had according to a Chi-square test no significant similarity ( $p = \text{ca}3.35\text{e-}42$ )



**Figure 4: Compared dietary data.** (A) Bar-plot portraying the proportion of the amount invertebrates found in the gut content compared the proportion of the amount invertebrates found in the benthic sampling within Göta älv. (B) PCoA visualizing similarities among the fish species based on the gut content composition with dietary data from juvenile Atlantic sturgeon (*Acipenser Oxyuranus*) from the Nanticoke River. The plot uses the Bray-Curtis distances. (C) A heatmap displaying the Bray-Curtis distance between the fish species based on their gut content with dietary data from juvenile Atlantic sturgeon (*Acipenser Oxyuranus*) from the Nanticoke river, 1 indicates a 100% difference while 0 indicates a 100% similarity in the diet composition between the compared species. Red in the colour gradient indicates a higher dissimilarity while blue indicates a higher similarity.

## 4. DISCUSSION

To summarize, a total of 89 fish and nine species were caught across the four sites in the Göta älv, with species distribution varying by location. Around 45% of the fish had identifiable gut contents, with each species possessing strong dietary preferences. For example, burbot and perch mainly consumed fish, while round goby and European flounder fed on Polychaetes. Dietary overlap was highest between round goby and European flounder (76%), and between burbot and perch (63%). Species diversity varied among the four locations, and gut contents did not reflect data of the benthic invertebrate composition. Diet comparisons showed that juvenile Atlantic sturgeon had the most similarity with round goby and European flounder, suggesting potential dietary overlap following the reintroduction.

### 4.1 Fish Composition at Each Location

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Location 1 exhibited the highest diversity index among all sites (Figure 2C). The comparatively high diversity can be linked to the capture of 44 individuals distributed across six species, representing higher richness and abundance than recorded at any other location (Figure 2B). Location 1 was also the most distinct site in terms of species composition, appearing as the most distant point in the PCoA analysis (Figure 2D) and exhibiting at least a 71% compositional dissimilarity relative to the other locations (Figure 2E). Round goby, European flounder, and European plaice were exclusively recorded at Location 1 (Figure 2A-B), whereas species such as perch, ruffe, and pike were found at two or more of the other sites. The distinctiveness of Location 1 is most likely linked to its geographical position in proximity of the river mouth (Figure 1) where it is presumably influenced by more saline water, thus enabling species typically associated with marine environments to occupy the habitat.

Locations 2 and 3 exhibited the greatest similarity in species composition, sharing 47% similarity in the composition (Figure 2E). However, these locations were geographically closest to each other (Figure 1). Burbot was the only species that was consistent in abundance across all sites, with 7 individuals recorded at Location 1, 5 at Location 2, 7 at Location 3, and 4 at Location 4 (Figure 2B).

Previous test fishing in Göta älv has shown that some of the most abundant species includes bream, ide, bleak and common dace. However, none of these was caught during the fishing, using fyke nets. The absence of ide, bleak and common dace can likely be linked to them preferring a more pelagic lifestyle further up in the water column and may therefore be able to

avoid bottom anchored fishing methods like Fyke nets. The Fyke nets should however be a suitable method for breams as they are primarily bottom dwelling. The lack of bream might therefore be linked to them occupying other types of habitats the ones being fished, rather than the fishing method itself.

## 4.2 Diet Composition

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Out of the nine fish species caught, seven had identifiable gut content which accounted for ~45% of all fish (Figure 3A). Each fish species had a preferred diet type consisting of more than 50% of its total diet (Figure 3B). Perch and burbot exhibited a shorter Bray-Curtis distance (Figure 3D) based on their diet preferences suggesting that they share a big portion of their diet composition, in this case their preference for fish. Most likely linked to their similar lifestyles as a predatory fish. Similarly, European flounder and round goby had shared a preference for Polychaetas also resulting in a shorter Bray-Curtis distance. This observed pattern could be explained by their shared lifestyles as bottom dwelling species associated with more saline water.

In contrast, the diet of roach almost exclusively consisted of plant fragments which none of the other species did. Likewise, ruffe was the only species that had a strong preference for Trichoptera. This resulted in these species repelling from the other species within the PCoA (Figure 3C), proposing that they have distinct diets in relation to the other species caught.

Pike and European plaice had no identifiable gut content and were therefore excluded from the diet analysis. However, based on their described lifestyles it could be assumed that the pike, as a predatory fish, would have a diet most relatable to the ones of other predatory fish such as perch and burbot, while the European plaice as a bottom dwelling species associated with salt water most likely would have a diet more equivalent to European flounder and round goby.

European eel were one of nine species that were caught during the fishing, it was however released immediately due to its endangered status. As a result, no dietary data were therefore retained, and no precise diet comparisons could be done in relation to the other species.

European eels do most likely, as a predatory fish, feed on smaller fish and bigger invertebrates, a diet that closely resembles a diet found in other predatory fish species, such as perch and burbot. However, the exact impact of European eel, European plaice, and pikes have on the food web within Göta älv cannot be determined without conducting some kind of dietary analysis on them.

Overall, the dietary data is based on relatively small sample sizes. For instance, the diet of the European flounder and perch is assessed based on two individuals each. As a result, individual preferences have most likely influenced the findings, making the results more reflective of these specific individuals rather than accurately representing the diet of the entire species in Göta älv.

### **4.3 Comparative Analysis with Benthic Invertebrate Fauna**

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The composition of invertebrates differs between the benthic sampling and the combined gut content data (Figure 4A), indicating that the fish species feed selectively, exhibiting preferences for certain types of invertebrates. Most notable however is that Chironomidae is the most abundant invertebrate within the benthic sample while it is completely absent within the gut content. This may likewise be explained by feeding preferences from the caught fish species, which may actively avoid consuming Chironomidae. Subsequently, if Chironomidae is not consumed by any fish species it could indicate a gap within the food web, something that the newly introduced Atlantic sturgeon could use to its advantage.

Alternatively, it is possible that Chironomidae are a preferred food source for fish species not represented within the gut content analysis, such as breams, something that might reduce its availability to other species. However, the lack of Chironomidae in the gut content could be a result of their fast decomposition within the gut, in comparison to other invertebrates. With this reasoning it is assumed that no Chironomidae would recently have been consumed prior to the fishing.

Reversely to Chironomidae, there was a high abundance of Trichoptera, Gammaridae, Ephemeroptera, and Polychaeta within the gut content despite their proportionally lower representation in the benthic fauna samples (Figure 4A). This may further support the theory of selective feeding from the caught fish species. As fish species selectively target their preferred prey, the resulting predation pressure may contribute to a reduced abundance of these invertebrates within the benthic community, despite still having a high representation in the gut content data.

### **4.4 Comparative Analysis with Published Atlantic Sturgeon Data**

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To predict how the reintroduced Atlantic sturgeon may come to interact with the Göta älv ecosystems, dietary data from juvenile sturgeons in Nanticoke river (located on the east coast of North America) were integrated into the PCoA and Bray-Curtis heat map based on the dietary

data of the caught fish species. The choice to use the Nanticoke river was because their dietary data were collected from juvenile Atlantic sturgeon. This is the part of their life that they are most keen to feed within rivers and therefore have a substantial impact on the ecosystem.

To properly integrate this data, the original food categories Polychaetas and Oligochaetes were combined, as the sturgeon data only described these prey items collectively as annelid worms. This combination however slightly altered the dynamics from the original plots, making it appear as though species feeding on Polychaetas versus Oligochaetes now have an increased similarity in their diets. For example, the round goby and ruffe have a 0% similarity in their diets in figure 3D while appearing to have a 11% similarity in figure 4C.

The juvenile sturgeon showed the highest dietary similarity (62%) with both round goby and European flounder (Figure 4C), due to their shared preference for annelid worms. However, this similarity assumes that the annelids within the sturgeon's diet includes Polychaetas. If, for example, the annelids instead consisted exclusively of Oligochaeta, the sturgeons would theoretically cluster closer together with the ruffe in the PCoA (Figure 4B), as neither the European flounder nor the black goby feed on Oligochaeta. Nevertheless, the sturgeon's placement in the PCoA remains relevant, as they share similar lifestyles by being bottom dwelling species. As the sturgeon share dietary similarities with the round goby and European flounder this might indicate where the sturgeons may come to thrive geographically, out of the four locations. This as the round goby and Europeans flounders only were found at location 1, closest to the estuary, suggesting that this would also be a suitable habitat for the sturgeon in relation to feeding opportunities on annelid worms.

The reintroduction of sturgeons will most likely affect the species of which it competes with, species it feeds on, and the species that might come to feed on them. As mentioned earlier European flounder and round goby share the same food preference as the Atlantic sturgeon and may therefore be big competitors, with the round goby being the most abundant of them (Figure 2B). Additionally, the round goby is an invasive species, which did not exist in Göta älv at the time when the sturgeon did, around 100 years ago, as it was first reported in Sweden 1990 (SLU, n.d.). Therefore, this may be a new threat to the sturgeon that it has not interacted with before, possibly complicating the reintroduction. Reversely, the reintroduction may have a positive effect, resulting in the Atlantic sturgeon potentially outcompeting the round goby, reducing their abundance.

Considering the diet compositions found in both the benthic fauna (Figure 4A) and the gut content (Figure 3A) compared with dietary data of sturgeon, it is most reasonable to assume that sturgeon will mainly feed on annelid worms. However, the sturgeon may also feed opportunistically on species that are of larger abundance such as that of Chironomidae and Oligochaeta (Figure 4A) that were not found in higher proportions of the gut content analysis (Figure 3A). The fish species that may come to feed on the sturgeon is the predators that feeds on fish. The most abundant predatory fish species within Göta älv according to this study was the burbot (Figure 2B) and might therefore be the most potent threat to the sturgeon predatory wise.

## **4.5 Net Placement**

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The fyke nets were placed at depths ranging from 1 to 6m, this relatively close to shoreline. The reason for this placement is partially to avoid interference from boat traffic, but also the faster current out in the mainstream, both with the probability to entangle the fishing gear. The net placement might, however, have biased the types of fish being caught, selectively favouring species adapted to shallower habitats and resulting in the underrepresentation of species thriving in the deepest parts of the river.

Fyke nets are a bottom-anchored fishing method, thus primarily favouring fish species associated with a bottom-dwelling lifestyle, such as ruffe, burbot or bream. Consequently, fyke nets may exhibit reduced efficiency in capturing fish species with a pelagic lifestyle, such as bleak, common dace or perch. In context of the Atlantic sturgeon project benthic associated species are however of greater interest, as these species exhibit ecological traits and spatial behaviours that are more likely to overlap and interact with those of sturgeons.

The selection of fyke nets as the fishing method was motivated by their comparatively higher post-capture survival rates relative to other suitable fishing methods such as gill nets, this enabling the release of endangered species, including any incidentally captured sturgeons. The fishing was however limited to four locations within the river, subsequently implying that even though the results may be representative for these specific sites, the given results might not be as representative for the river in its entirety. This as the river most likely alter in habitat dynamics throughout the river and with it the ecological composition.

## 4.6 Time Period of Fishing

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The time period of the fishing has most likely influenced the results of the project. This as most organisms follows seasonal behaviours. Both fish species and organisms from a lower trophic level follows behaviours such as spawning, adjusting to temperature and adapting to food availability which is for the most part strongly linked to the different time periods of the year. Potentially resulting in the fish occupying different types of habitats and shifting their diet depending on different circumstances following seasons and temperatures. A fishing and a stomach analysis conducted in October will therefore to some extent most likely play out different than if it was done at a different time period at the year.

## 4.7 Future Research

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By diversifying the fishing methods, a broader range of fish species could be retained. Using methods such as pelagic nets or electrofishing as complementary fishing methods to the fyke nets would most likely result in a bigger variety of fish species with other ecological niches than those already caught from the fyke nets. Including these methods would likely enhance the depth of the analysis, allowing for a more precise determination of how the ecosystem operates. To minimize the influence of different seasons and temperatures, the fishing would likewise benefit from being conducted on several occasions spread throughout the year.

By expanding the fishing and thereby retaining a larger number of fish, the resulting increase in sample size would provide a more accurate dietary data from the fish species of Göta älv. This would reduce the influence of individual variation and preferences within the dataset.

By conducting DNA-analysis of the gut content, more detailed and precise dietary data would be obtained. Potentially unveiling dietary content that would be difficult or impossible to determine through the used microscopic analysis. A suitable approach for this would be metabarcoding.

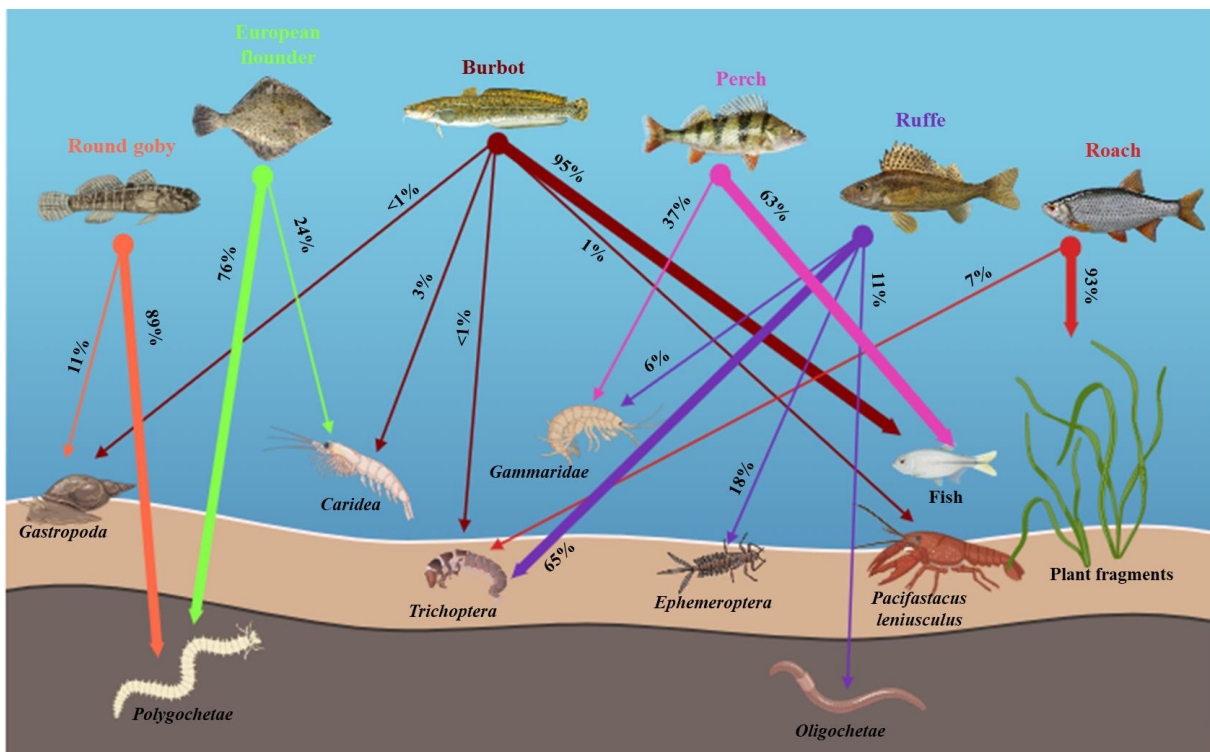
To further evaluate the interaction between the reintroduced Atlantic sturgeons and other species within the ecosystem, more detailed dietary data from sturgeons is required. This can be achieved by analysing gut contents of recaptured Atlantic sturgeons from the project, using methods such as stomach-flushing to avoid sacrificing the fish. This data would provide precise information on their dietary preference within Göta älv, allowing for a more accurate assessment of their ecological interaction with other organisms.

## 5. CONCLUSION

Understanding the complex food web dynamics within Göta älv is essential to establish predictions regarding how the Atlantic sturgeon might come to interact with the ecosystem following its reintroduction.

In this study the gut content of caught fish species within Göta älv was determined, uncovering their diet composition (Figure 5). This revealing dynamics regarding predation and competition among the fish species and their prey. Furthermore, comparative investigations to benthic invertebrate fauna reveals potential patterns, suggesting that the fish species feed selectively, also displaying Chironomidae as an unutilized food source in the food web. Additionally, the study sheds light on possible impacts of reintroducing the Atlantic sturgeon, such as its possible competition with the species such as European flounder and round goby, as they are indicated to share a similar food preference.

Although more research is needed to fully understand the complete dynamics of the ecosystem within Göta älv and how the Atlantic sturgeon might come to affect it, this study provides a good foundation for future research.



**Figure 5:** Graphical illustration of the diet proportions within Göta älv for each caught fish species with identifiable gut content. Each fish species is indicated by a specific colour and bold arrows represents the most dominant diet preference for the fish species. Created with BioRender.com.

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