3.3. Foodwebs in the Baltic Sea

3.3.1 Status of Baltic Sea foodwebs

Food webs represent the feeding relationships among species and populations (Figure 3.16). Understanding food webs is critical for comprehending key ecosystem interactions and the food/energy flows that underpin ecosystem health and productivity. Impacts on the status of Baltic Sea food webs occur through effects on the species that interact within them, as these effects are mediated to other species and trophic guilds (Eero *et al.* 2021). Alterations in the structure of food webs influence their functions and ecosystem processes, such as ecosystem productivity, stability and resilience against future pressures. Available evidence shows that major changes in the abundance and biomass of species, driven by human pressures, have been associated with changes in the food webs of the Baltic Sea in recent times. Several examples of food web disruption and putative tipping points are cause for concern.

Why is this important?

Healthy food webs are fundamental to the functioning of the Baltic Sea ecosystem and its delivery of ecosystem services.

Food webs ensure the productivity and energy flow in the aquatic system, whereby energy produced by algae and plants is transferred to animals, supporting a diversity of zooplankton, benthic fauna, fish, marine mammals and waterbirds.

Food webs in good status can ensure the stability of ecosystem processes and the ecosystem's resilience against current and future pressures, including climate change.

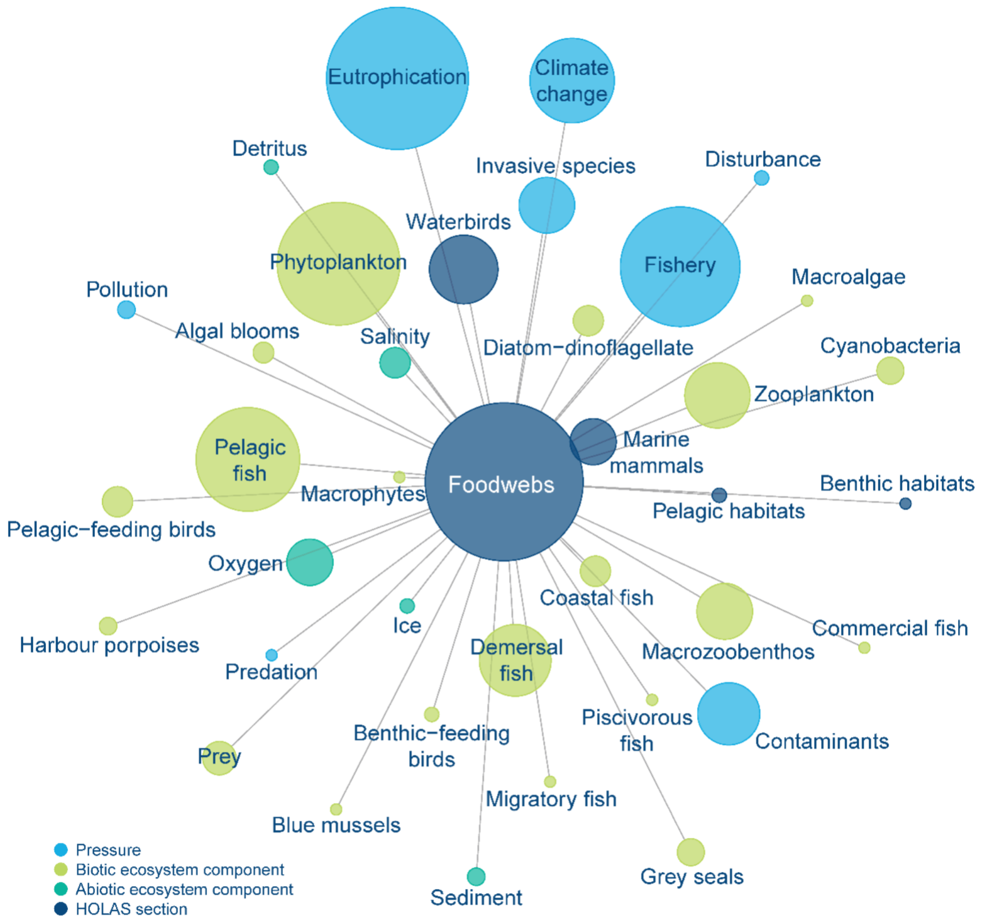

Figure 3.16. An overview of the ecosystem components and pressures descriptively linked to the status of food webs in HOLAS 3. The figure reflects aspects highlighted in the chapter on this topic in the HOLAS 3 thematic assessment report on biodiversity (HELCOM 2023a), based on the terms used and interlinkages made. The chapter itself is symbolised by the dark blue circle in the centre, and the other circles represent the key elements (terms) used in the chapter. The size of each circle is based on how often the term is mentioned in the chapter and should only be interpreted in this way. The terms are aggregated, so each circle includes both the term itself and all terms deemed to be synonymous (e.g. "eutrophication" includes "eutrophication" and associated terms such as "nutrient input" or "concentrations"). The width and length of the lines and the placement of the items is arbitrary. The image gives a simple visual representation of the topics covered in the evaluation, while simultaneously providing a gap analysis of where more information may be required in the future to increase the holistic nature of the evaluation (e.g. if an interaction between a certain pressure and an ecosystem component has not been well addressed). The overview was made using igraph.

What is affecting the status of food webs in the Baltic Sea?

It is challenging to identify the direct relationship between the status of food webs and any particular pressure. Several pressures often act simultaneously on different parts of the food web. These pressures could have effects through direct or indirect links, and the effects may occur with a time lag. However, pressures that have clearly been associated with an effect on food webs in the Baltic Sea include fishing, eutrophication, contaminants and non-indigenous species.

Fishing has played a key role in driving food web changes in several parts of the Baltic Sea where strong declines in predatory species have led to cascading effects. The most notorious example is the collapse of the eastern Baltic cod stock in the late 1980s and early 1990s, attributed to the combined effects of overfishing, changes in the climate and eutrophication (Möllmann *et al.* 2009). This led to a chain of effects on the offshore food web of the Baltic Proper (Casini *et al.* 2008, Tomczak *et al.* 2012, Blenckner *et al.* 2015). Similar effects were also seen elsewhere, including in the Gulf of Riga (Casini *et al.* 2012). Cod stocks have not yet recovered, and the resulting impacts on Baltic Sea food webs remain present and persistent, indicating that a recovery of the food web will also require addressing several currently ongoing pressures.

Since coastal areas and open sea areas are connected, impacts in the open sea also have implications for coastal areas and vice versa (Eriksson *et al.* 2011, Olsson *et al.* 2015, Tomczak *et al.* 2016). Ongoing regime shifts have recently been observed in coastal areas, relating to the enhanced dominance of stickleback (Eklöf *et al.* 2020) and the role of herring in regulating zooplankton abundance (*Limnocalanus macrurus* in the Gulf of Riga, Einberg *et al.* 2019). The collapse of the western Baltic cod and the western Baltic spring-spawning herring stocks during the current assessment period indicates further deterioration (HELCOM 2023a) which is associated with negative consequences on, for example, harbour porpoises (Scotti *et al.* 2022a).

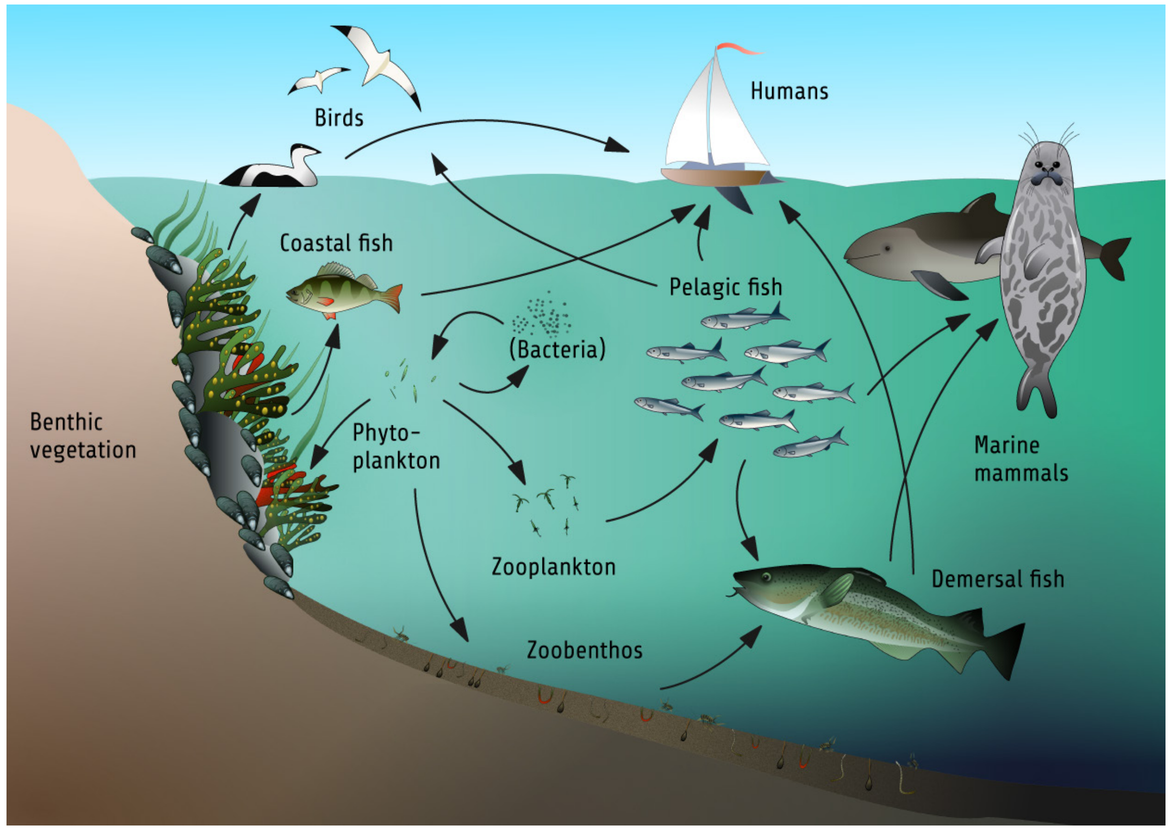

Figure 3.17. The Baltic Sea food web includes primary producers, which make energy and nutrients available to the ecosystem, primary consumers, which feed on the primary producers, and different levels of predators, which feed on lower trophic levels. It also includes species that use dead organic material and contribute to recycling energy and nutrients, and some species function as parasites. Natural food webs are often highly complex, as there are many links between species and a variety of feeding relationships.
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Eutrophication is associated with effects on species composition in several key trophic groups in the Baltic Sea, such as pelagic primary producers, benthic fauna, coastal fish and waterbirds (HELCOM 2023a). Eutrophication has had far-reaching direct and indirect impacts on Baltic Sea food webs, not only changing the trophic state of the ecosystem but also affecting higher trophic levels (Tomczak *et al.* 2022). Since the 1920s, the Baltic Sea has transformed from being a typical low productivity aquatic system to a high productivity system in which the presence of insufficient oxygen conditions is a main regulatory driver. Climate change is expected to worsen the negative impacts of eutrophication on food webs through, for example, increased algal blooms and oxygen consumption.

Hazardous substances can have direct toxic effects or damage habitats and accumulate within the tissue of biota. Substances with the potential to accumulate in the food web can affect the health and abundance of species through trophic dynamics. For example, accumulating evidence supports the biomagnification and health consequences of methylmercury (Vainio *et al.* 2022), population declines related to persistent organic pollutants (Sonne *et al.* 2020), and transgenerational effects in Baltic biota (Mauritsson *et al.* 2022). The same contaminant can also have different effects in different types of food webs, and its biomagnification might be affected by how benthic and pelagic habitats are connected (Vainio *et al.* 2022).

Top predators can serve as indicators of persistent harmful substances in the ecosystem. Because persistent chemicals accumulate in the food web, emerging pollutants that are below the detection limits in other biota could be detected in top predators, such as the white-tailed eagle (*Haliaeetus albicilla*) (Helander *et al.* 2008, Badry *et al.* 2022) and marine mammals (UBA 2022).

Several non-indigenous species have been attributed to impacts on biotic properties in the Baltic Sea (Ojaveer *et al.* 2021). Among these, the predatory cladoceran *Cercopagis pengoi* and the zebra mussel (*Dreissena polymorpha*) have been attributed to the highest impacts on food webs. Based on biotic properties, the largest impact has been attributed to non-indigenous species that are a prey for native species. However, the effect varies strongly between species. The polychaete *Marenzelleria* spp., the mud crab *Rhithropanopeus harrisii*, the round goby *Neogobius melanostomus* and the zebra mussel are non-indigenous species that have taken major roles in the Baltic Sea food web, leading to effects at multiple trophic levels and in multiple habitats. There is also evidence that a non-indigenous species (*R. harrisii*) can function as a driver of regime shifts in the Baltic Sea (Kotta *et al.* 2018).

Effects of climate change on food webs

Climate change can influence several processes that affect the status of food webs, such as species interactions, nutrient recycling and ecosystem properties (HELCOM/Baltic Earth 2021). Impacts can occur by direct effects on the physiology or biology of species or through bottom-up and top-down cascading effects, mediated by changes in productivity or predation patterns, for example (e.g. Casini *et al.* 2009, Hjerne *et al.* 2019, Kahru *et al.* 2014, 2016, 2020). Furthermore, climate change is very prone to interacting with other pressures. In the Baltic Sea, changes in climatic conditions in combination with fishing and eutrophication have been attributed to shifts from larger to smaller zooplankton, stronger impacts of nutrients on ecosystem structure, and reduced regulatory capacity of predators (HELCOM/Baltic Earth 2021). Altered inputs of hazardous substances, changes in the how species are exposed to them, and potentially in how they are transferred in food webs may also be relevant.

Due to these complex interactions, the effects of climate change on higher trophic levels are expected to differ between organism groups (Helenius *et al.* 2017, Lindegren *et al.* 2012, Olsson *et al.* 2012, Niiranen *et al.* 2013, Svensson *et al.* 2017, Pecuchet *et al.* 2013). Current knowledge is limited to what can be observed or deduced about future conditions under current climatic conditions, and there are knowledge gaps on how food web structure, functioning and resilience may change under expected future environmental conditions (HELCOM/Baltic Earth 2021).

Another knowledge gap concerns responses to extreme events, such as heat waves (Humborg *et al.* 2019, HELCOM/Baltic Earth 2021). For example, a mesocosm experiment showed that consecutive heat waves could have different effects on different benthic fauna species in coastal ecosystems of the western Baltic Sea. Positive effects were seen on some species (amphipods) and negative effects on others (tellinid bivalves), highlighting how the same stress factor yields diverse responses that contribute to reshaping the food web (Pansch *et al.* 2018).

What can we do?

Food webs are not possible to manage directly, but the status of food webs benefits from strengthening its key components and from the proper management of the human activities that causes pressures on them, such as eutrophication, fishing pressure, contaminants, and non-indigenous species. The status of food webs also benefits from measures to reduce the effect of climate change. The establishment of a network of strictly protected areas is an important tool to ensure functioning food webs now and in the future.

Furthermore, understanding the structure and function of food webs is helpful for the implementation of measures generally (Eero *et al.* 2021, Nordström *et al.* 2021). Food web knowledge helps us understand the ways in which different species in the Baltic Sea are dependent on each other and how the effects of pressures, and pressure management, might manifest. Information about food webs is therefore key for designing efficient measures to improve and strengthen environmental and marine management, including the development of ecosystem-based management.