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European Regional Development Fund

Native and non-native invertebrates from the Baltic Sea: food source for humans or in the future aquaculture

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Overview

- Changes observed in environment, aquaculture and people
- Products from the sea and their value, especially fatty acids
- The Baltic Sea and indigenous and non-indigenous benthic species
- Lipids and fatty acids in the Baltic invertebrates
- Questionnaire
- Breeding experience with invertebrates in other regions
- Conclusions and questions

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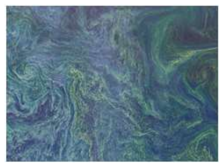
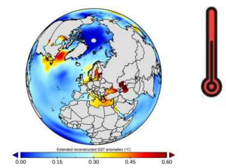
Global changes in marine ecosystems

Main global changes: Overfishing, eutrophication, pollutants, temperature rise





Biodiversity → Ecosystem functioning → Fish production

↓

Economic and social consequences

HELCOM, 2010, 2018, Reusch et al. 2018, photos: OCEANA/Carlos Minguell Copernicus Sentinel data/ESA (CC BY-SA 3.0), Kaj Granholm, HELCOM Secretariat

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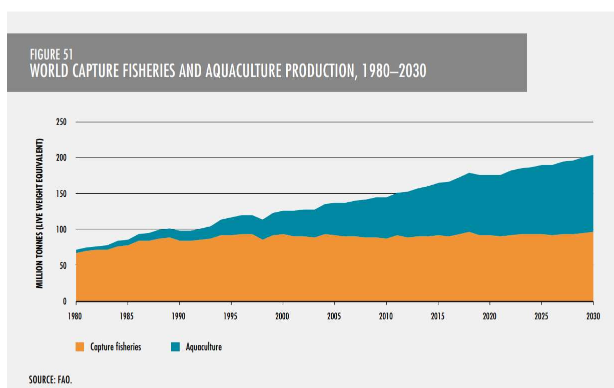
Aquaculture

- Aquaculture continues to grow faster than other major food production sectors. It's share in global production of marine organisms will increase in the near future.
- Fish meals and oils used as fish feed have been gradually replaced by plant meals and oils from agriculture which resulted in changing the nutritional value of fish.



FAO 2018

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Increase of human population and changes in consumer attitudes and habits

- Global population is growing and thus food demand will increase;
- Additionally, aquatic animals consumption grew from 9.0 kg in 1961 to 20.3 kg per capita in 2017;
- In 2017, consumption of fish in Poland was 12.4 kg per capita, this is about half of the EU average;
- Changes in attitude resulting in reductions in loss and waste. Sustainable Development Goal (SDG) Target 12.3, aims at halving wastage by 2030;
- Increasing awareness of the health benefits of sea food among consumers.

FAO 2020, https://www.eurofish.dk/poland

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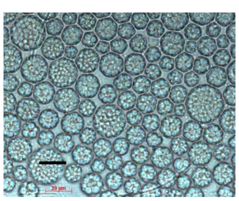
New sources of food

- Where to search for good food source?



Cells *Schizochytrium* showing numerous lipid bodies

Sea lettuce *Ulva lactuca*

Blue mussel *Mytilus edulis*

Brown shrimp *Crangon crangon*

- More sustainable marine food production strategy should focus on lower trophic levels.

Raghukumar 2008, van der Meer 2020, photos. en.wikipedia.org, M. edulis: Andreas Trepte, C. crangon – R. Brzana

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What is most valuable and unique in marine organisms?

- Vitamins
- Minerals
- Proteins
- Lipids
  - **Long-chain poly-unsaturated fatty acids (LC-PUFAs)** which are unsaturated fatty acids consisting of 20 carbons or more and **come mainly from marine organisms.**
    - Essential fatty acids (EFAs)

Glencross 2009, Nichols et al. 2010

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Essential fatty acids

Essential fatty acids (EFAs) - The term "essential" is used because of their bioactive nature and the fact that presence of some fatty acids has a significant positive effect on animal growth.

- ARA arachidonic acid (20:4ω6)
- EPA eicosapentaenoic acid (20:5ω3)
- DHA docosahexaenoic acid (22:6ω3)

Glencross 2009 and publications therein, Parrish 2013, Cholewski et al. 2018

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Importance of essential fatty acids (EFAs) for aquatic animals

- ARA and EPA – in reproduction (e.g. hatching, larval development and survival of crustaceans and fish);
- DHA – in the neural, visual and sperm cells in many animals, particularly in fish;

- **Essential fatty acids** play an important role in the function of the **immune system** in fish;
- Cardiac diseases, autoimmune disorders and inflammatory disorders are exacerbated with an increase in dietary omega-6 to omega-3 ratio.

Glencross 2009 and publications therein

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Important findings

- In fish transformation of alpha-linolenic acid (αLNA) to LC-PUFAs (e.g. EPA + DHA) is very limited. So, most of LC-PUFAs should be taken with marine food.
- Many studies with different fish species have shown that fatty acid composition of fish muscle reflects that of their diet.

αLNA --- < 10 % ---> Anti-infammatory LC-PUFAs

de Deckere et al. 1998, Glencross 2009 and publications therein

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Lipids and fatty acids

- **The lipids content and fatty acids composition of invertebrates and fish varies between species and depend on nutritional state**, which is affected by:

- season,
- food availability,
- age, sex,
- developmental or reproductive status.

Glencross 2009 and publications therein

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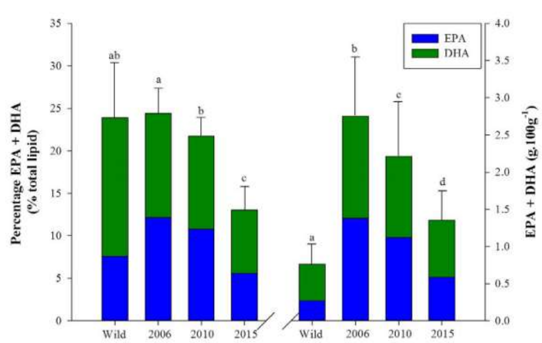
Changes in aquaculture

Farmed Atlantic salmon *Salmo salar*

- The use of plant ingredients in salmon feeds has accelerated since 2009,
- This has caused a decrease in EPA+DHA concentration in fish from aquaculture
- Marine fatty acids EPA+DHA in fish fell by approximately half.

A single 130 g portion of Scottish salmon farmed in 2006 would have been adequate to meet the need of **3.5 g EPA+ DHA** weekly, whereas in 2015 this would have required two portions.



Differences in the proportions [% FA] and absolute level [g 100 g-1] of EPA+DPA fatty acids between wild (Pacific species) and farmed Scottish Atlantic salmon from 2006, 2010 and 2015.

Sprague et al. 2016

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Studies on rainbow trout *Oncorhynchus mykiss*

100% plant-based diet negatively affect:

- Survival
- Body mass
- Metabolism
- Fatty acids profile

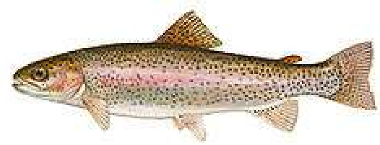
Table 5. Amounts of EPA + DHA (g fish^{-1}) at different developmental stages in response to the experimental diet.

	EPA + DHA			
	Juveniles		*Ongrowing fish*	
Diets	Mean	SD	Mean	SD
Diet-M	0.20[a]	0.01	8.9[A]	1.12
Diet-C	0.08[b]	0.004	5.4[B]	0.37
Diet-V	0.01[c]	0.002	0.9[C]	0.07

Diet-M: marine diet (77 % FM+FO)
Diet – C: commercial like & plant-based diet(38 % FM+FO)
Diet-V – experimental 100% plant based diet
FM+FO - fish meal+ fish oil

EFAs rich diet positively affect:

- feeding behavior (they choose food rich in EFAs)
- brain functions



Lazzarotto et al. 2018, Roy et al. 2020 a,b,, photo: pl.wikipedia.org

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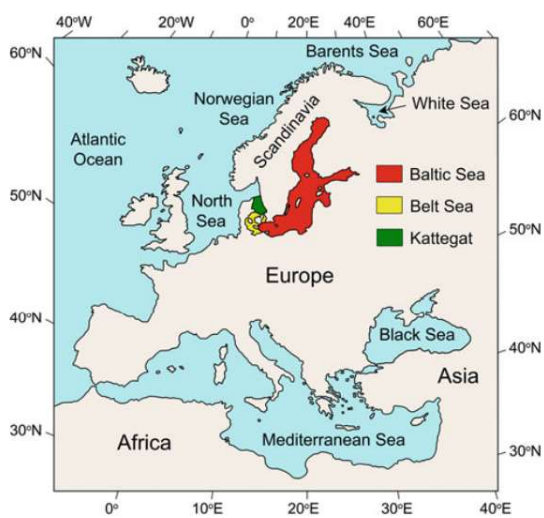
The Baltic Sea - indigenous and non-indigenous species living there



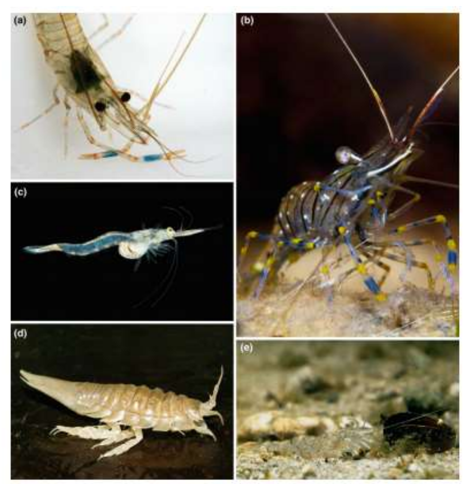


Fig. 4.25 Some crustaceans that are abundant in the Baltic Sea. (a) The native Baltic Sea shrimp *Palaemon adspersus*. (b) The non-indigenous shrimp *Palaemon elegans*. (c) The mysid *Neomysis integer*. (d) The Arctic relict isopod *Saduria entomon*. (e) The brown shrimp *Crangon crangon*. Photo: (a, d) © Pauline Snoeijs-Leijonmalm, (b) © Stefan Beskow/Azote, (c) © Nicklas Wijkman/Azote, (e) © Gunnar Ansen/Azote

Snoeijs-Leijonmalm &. Andrén, 2017, www.coastalwiki.org

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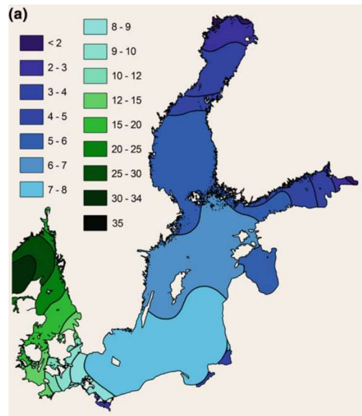
The Baltic Sea

- **The semi-enclosed shallow and brackish basin;**
- Mean depth about 60 m (max. depth 456 m);
- Salinity 20 – 2;
- Temp. < 0°C in winter to > 20°C in summer;
- Anthropogenic stressors (overfishing, eutrophication, hazardous substances).



The salinity gradient of the Baltic Sea Area

Bonsdorff 2006, Snoeijs-Leijonmalm &. Andrén, 2017

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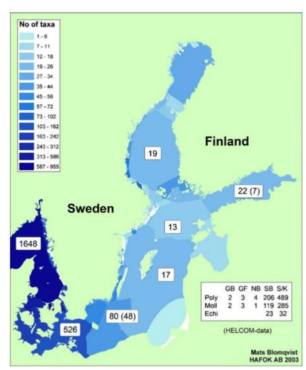
Benthic species richness

- In the Baltic Sea number of species declines rapidly with the decrease of salinity;
- Many species reach their physiological limits of tolerance;
- Some species are smaller in the Baltic Sea than in fully saline water e.g. *Mytilus trossulus, Crangon crangon.*



Distribution of soft-sediment species richness across the Baltc Sea evironmental gradient

Bonsdorff 2006, Snoeijs-Leijonmalm. 2017, Photo: Hans Kautsky

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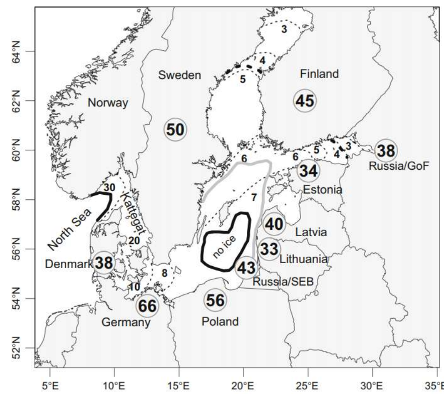
Non-indigenous species in the Baltic Sea

- Around 132 non-indigenous species or cryptogenic species have so far been recorded;
- Most of the taxa belong to zoobenthos or nektobenthos (> 50%);
- In total 24 benthic non-indigenous species live in the Gulf of Gdańsk.



Total number of non-indigenous species and cryptogenic species recorded by country

Ojaveer et al. 2016, Janas & Kendzierska in.prep.

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Palaemon elegans

- Body length: 60 mm;
- Non-indigenous species in the Baltic Sea;
- Broad range of temperature and salinity tolerance (>0);
- Omnivorous species;
- Food item for many fish species for example cod, perch;
- Caught on a small scale for human consumption (e.g. along the Atlantic and Mediterranean coasts) or to be used as fishing bait.

Janas & Mańkucka 2010

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The Baltic prawn *Palaemon adspersus*

- Body length: 70-80 mm;
- Broad range of temperature and salinity tolerance (>5);
- Food item for many fish species;
- Caught on a small scale for human consumption in e.g. along the Atlantic and Mediterranean coasts of Europe the Black Sea and the Baltic Sea (Germany);
- Aquaculture production on small scale: 5 tons in Ukraine in 2007-2011.

FAO Aquaculture, Capture and Global Production Databases

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Platorchestia platensis

- Amphipods - Talitridae
- Non-indigenous species in the Baltic Sea;
- Body length ~10 mm;
- The species lives on the beaches;
- Important consumers of the stranded macrophyte detritus;
- Food web: Talitrids play an important role in the food web and they serve as a link between marine and terrestrial ecosystems;
- They are important food for birds;
- High density up to 7000 ind.m^{-2}

Tykarska et al.. 2020, photo Piotr Wysocki

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Saduria entomon

- Body length: 84 mm;
- Water temperature tolerance: stenothermal, cold-water (rarely exceeding 5°C);
- Salinity tolerance: euryhaline 0-15;
- Omnivorous, scavenger;
- It is a valuable component in the diet of fish such as sculpin *Myoxocephalus scorpius* and commercially important species like cod *Gadus morhua* and flounder *Platichthys flesus.*

Green 1957, Leonardsson et al. 1987, Borecka et al. 2016, photo. Piotr Wysocki

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The Baltic clam *Limecola balthica*

- Length up to 24 mm;
- Principal macrofaunal component in the Baltic Sea;
- Live on different type of soft sediment;
- Euryhaline species, capable of living in a wide range of water salinity, down to 3-4;
- Facultative suspension/deposit feeder;
- Important food for invertebrates, fish.

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Rangia cuneata

- Size up to 5 cm and very thick shells;
- Non-indigenous species in the Baltic Sea;
- Native for the Gulf of Mexico and Atlantic coast;
- First recorded in European waters in the harbor of Antwerp (Belgium) in 2005;
- In 2010-2011 found for the first time in the southern part of the Baltic Sea;
- Filter feeder;
- It was popular food for native Americans and early settlers of South Luisiana and today **is still consumed by local fishing communities**. The shell of *R.cuneata* had been used as roadbed materials.

Verween et al. 2006, Rudinskaya & Gusev 2012, Warzocha & Drgas 2013, Janas et al. 2014, photo Piotr Kendzierski

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Questions

- Can we use the Baltic invertebrates as valuable food in aquaculture?
- Can we eat them?
- Can we use them for transforming waste into products with high content of EFAs?

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Preliminary study on the Baltic invertebrates

The aim of the study was to quantify fatty acids composition of the Baltic benthic invertebrates and to compare its essential fatty acids (EFAs) with plants, other marine invertebrates and fish.

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Materials and methods

- Four species of crustaceans and two of bivalves were collected in the Gulf of Gdańsk;
- Lipids and fatty acids were measured:
  - Total lipids were measured after Folch extraction;
  - Fatty acids were analysed by gas chromatography.

Saduria entomon

Palaemon elegans and *Palaemon adspersus* – max. length 67 mm

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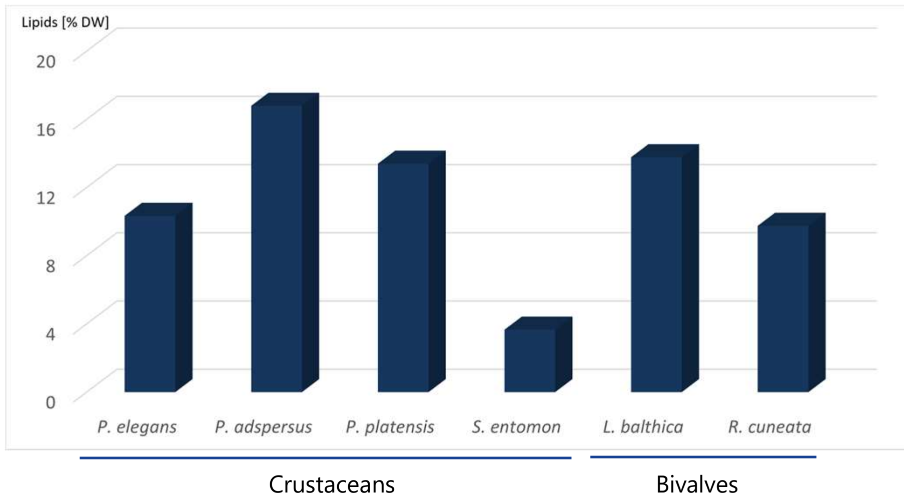
Lipids

- Lipids content in benthic invertebrates varied from 3.7 to 17 % DW (dry mass).
- The difference in lipid content of two species of prawns could be connected with food.
- Very low lipid content of *S.etomon* results from massive carapaces.



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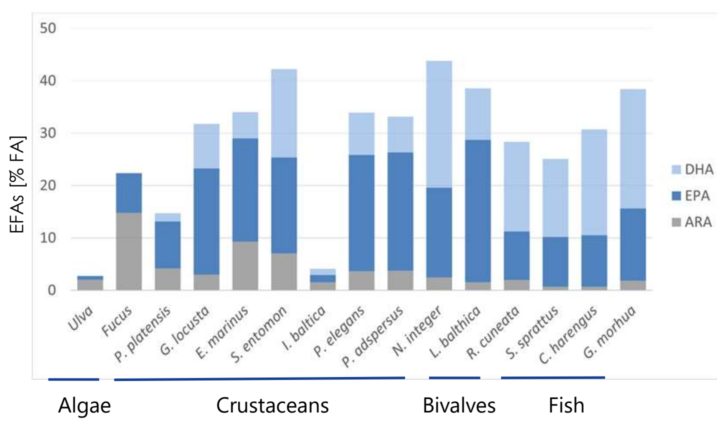
Essential fatty acids

- Content of three most important EFAs varied from < 5 % for Ulva and from 10 % for to 44 % for invertebrates.
- In general, higher content of EPA was found in invertebrats whereas DHA in fish.



Platorchestia platensis, Palaemon elegans, Palaemon adspersus, Limecola balthica, Rangia cuneata – own preliminary results,; Ulva, Fucus, *Gammarus locusta, Echinogammarus marinus*, North Sea, Alberts-Hubatsch et al. 2019; *Idotea baltica* - Mediterranean Sea, Prato et al.. 2011; *Neomysis integer* – Baltic Sea, Grzeszczyk-Kowalska et al. 2014; *Sprattus sprattus, Clupea harengus* – Baltic Sea, Røjbek et al. 2014; *Gadus morhua* – Atlantic, Budge et al..2002

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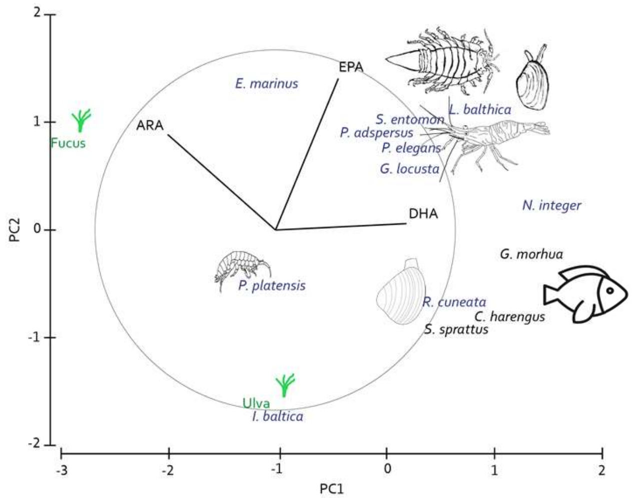
Essential fatty acids



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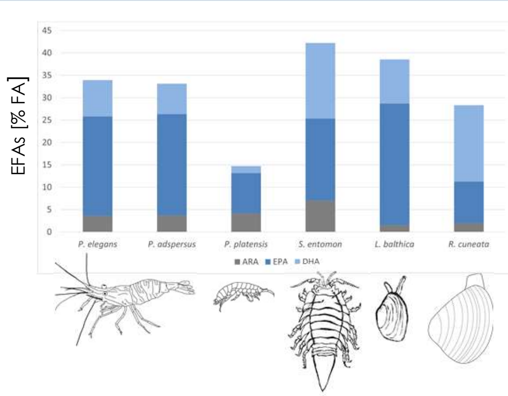
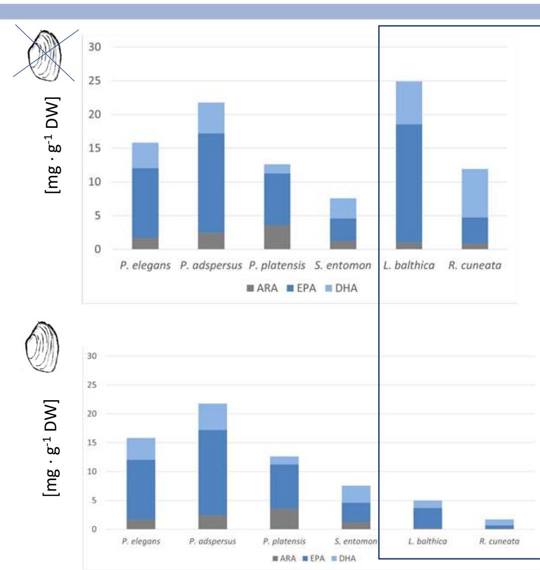
Qualitative and quantitative data on EFAs in the Baltic invertebrates



Prawns – *Palaemon elegans* and *Palaemon adspersus*
Talitrid – *Platorchestia platensis*
Isopod – *Saduria entomon*
Bivalves- *Limecola balthica* and *Rangia cuneata*



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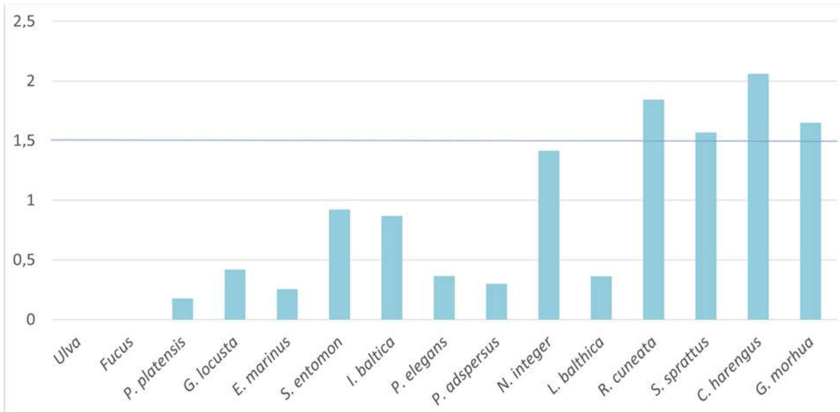
DHA:EPA ratio

- DHA:EPA ratio around 2:1 has been recommended for larval nutrition



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Aquaculture experience with invertebrates in other regions

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Palaemon elegans

Conclusions from small scale aquaculture on the Black Sea coast

The species is:

- not demanding at feeding - accepts and consumes artificial food;

- able to reproduce in controlled conditions, in order to provide viable juveniles to be used in breeding;

- accepted by the consumers.

Autdoor basins: 5x10x1.5 m

Zaharia et al.. 2006

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The grass shrimp *Palaemon varians*

The grass shrimp is a good live food for:

- the culture of cuttlefish *Sepia officinalis* throughout the life cycle;
- species of the Syngnathidae family.

Sykes et al. 2006, Palma et al. 2008, photo: en.wikipedia.org

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Amphipods

Marine amphipods are an interesting potential aquaculture resource

- Important natural dietary component for fish;
- Some species show wide environmental tolerances;
- Opportunistic feeders are able to feed on detritus. Therefore, they could be incorporated in 'Integrated Multi-Trophic Aquaculture' (IMTA) to recycle detritus;
- Contain high levels of beneficial PUFAs, high protein content and adequate amino acid profile.

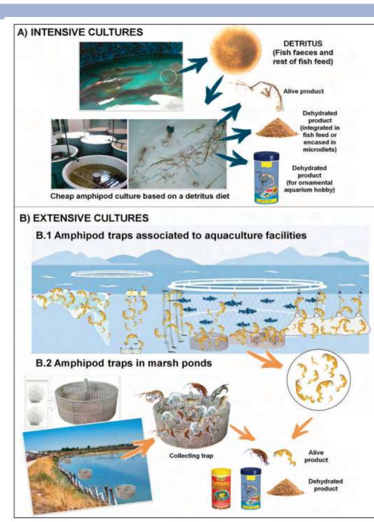

Figure 1. Intensive amphipod cultures in tanks (A) and extensive amphipod cultures in structures (nets, buoys, cages, lines) placed in the aquaculture facilities (B1) or in collecting traps associated to marsh ponds in Southern Spain (B2).

Guerra-García et al., 2017 and publications therein; Jiménez-Prada et al. 2018

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Platorchestia platensis

- *Platorchestia platensis* was used as protein source for rearing aquarium fish guppy *Poecilia reticulata;*
- Amphipod based food (containing 25% of amphipods) was used.
- The growth was similar to growth using commercially available feed but 10 times less expensive.
- Powdered form of amphipod based food was preferred compared to flakes and pellets.

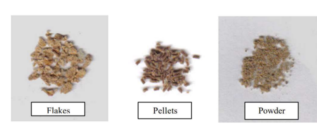

Figure 1: The different textures of Amphipod-based feeds prepared during the study. From left to right flakes, pellets and powdered forms of AF.

Appadoo & Saudagur 2007, photo: Hans Hillewaert

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Mysidacea

- **Mysids** are filter feeders, omnivores that feed on algae, detritus and zooplankton, carnivores;
- **Difficult to keep alive in captivity**
- Many small crustaceans, especially mysids (e.g. *Hemimysis anomala*), were transferred to other water-bodies within the former Soviet Union in the 1950s and 1960s;
- Frozen mysids are used as food for aquarium pets.

Salemaa & Hietalahti 1993, Leppäkoski & Olenin 2000, Woods & Valentino 2003, photo Piotr Wysocki

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Sum up

- There are invertebrates in the Baltic Sea rich in EFAs with a potential to be used as food for people or feed in aquaculture.

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Sum up

- Apart from the fact that we eat too little fish, there is no tradition of eating algae, bivalves or crustaceans in the Baltic region.
- The shift in eating habits is necessary.

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