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EUROPEAN UNION

European Regional Development Fund

Worms... – about the use and benefits of worms in aquaculture

University of Rostock

Aquaculture & Sea-Ranching

Faculty of Agricultural and Environmental Sciences

Presenter: Dr. Adrian A. Bischoff-Lang

Included scientific staff: Prof. Dr. Harry Palm

M.Sc. Jan Klein

M.Sc. Philipp Sandmann

M.Sc. Sven-Ole Meiske

Contents of the presentation:

- General introduction to the topic and why worms?

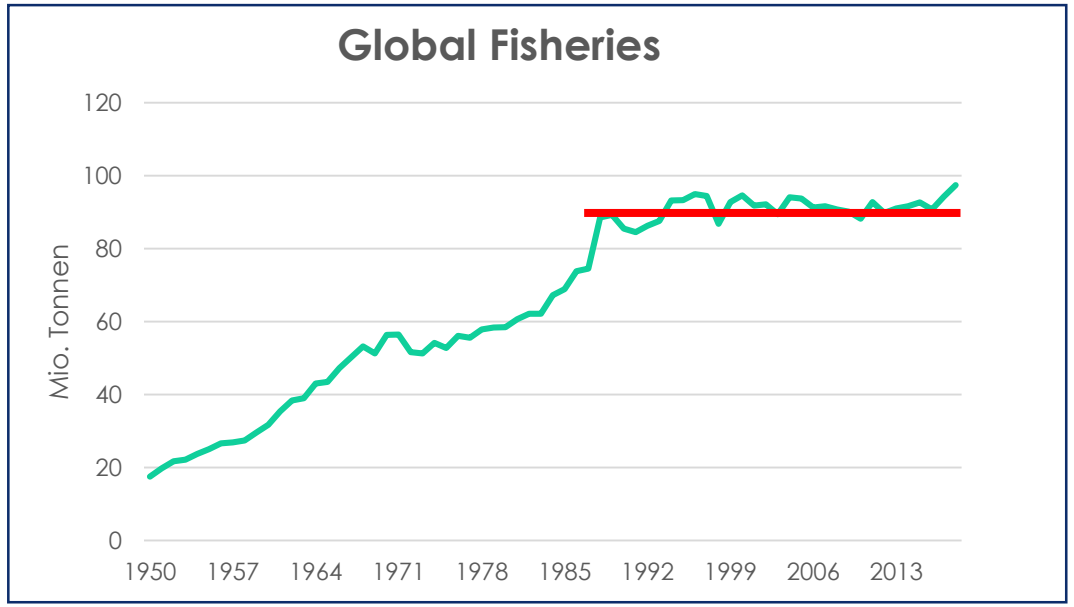
- Case studies on worm aquaculture
  - Bischoff 2003 & 2007; Bischoff et al. (2009) Bischoff et al. (2014)
  - Sandmann (2018 – Master thesis); Meiske (2021 – Master thesis)

- Research projects
  - IntAPol – Integrated Aquaculture of Polychaetes (Original title: Integrierte Aquakultur von Polychaeten)

General Introduction: Fisheries & Aquaculture…

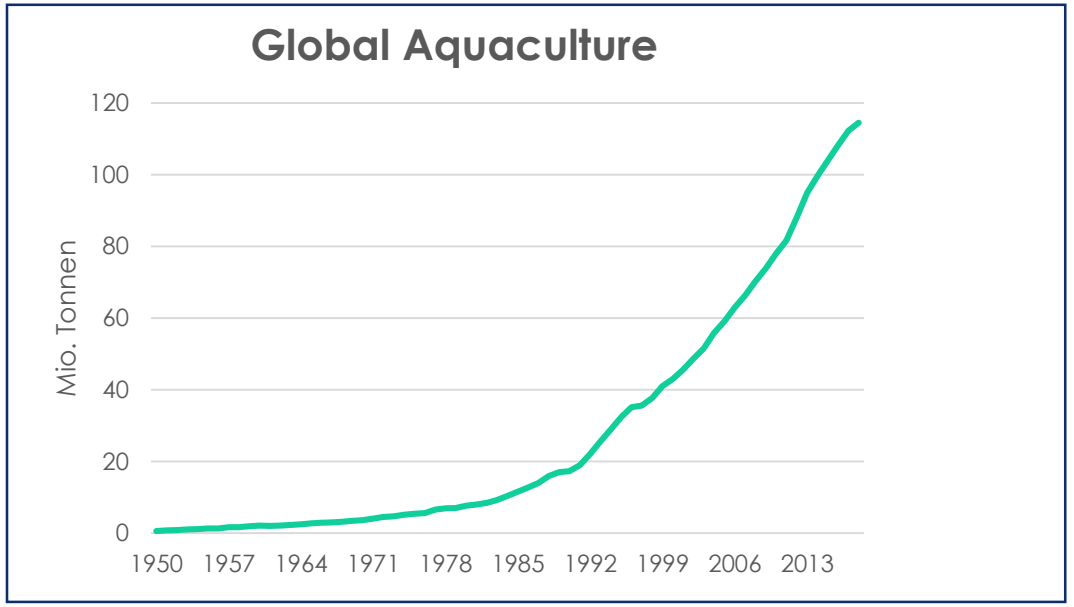
Global Fisheries

- stagnating



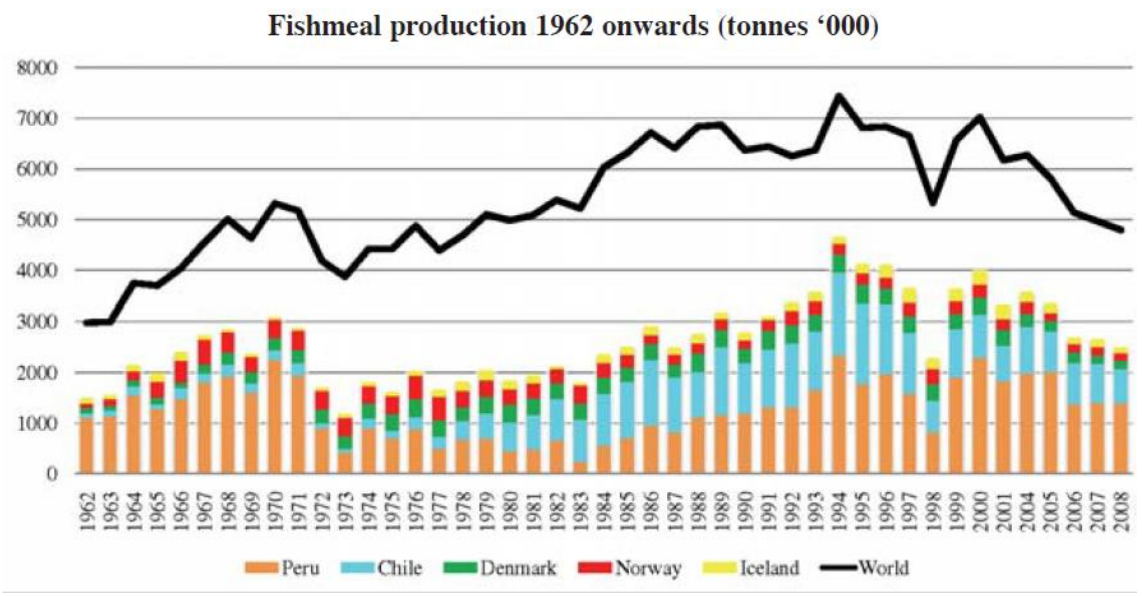
Global Aquaculture

- increasing

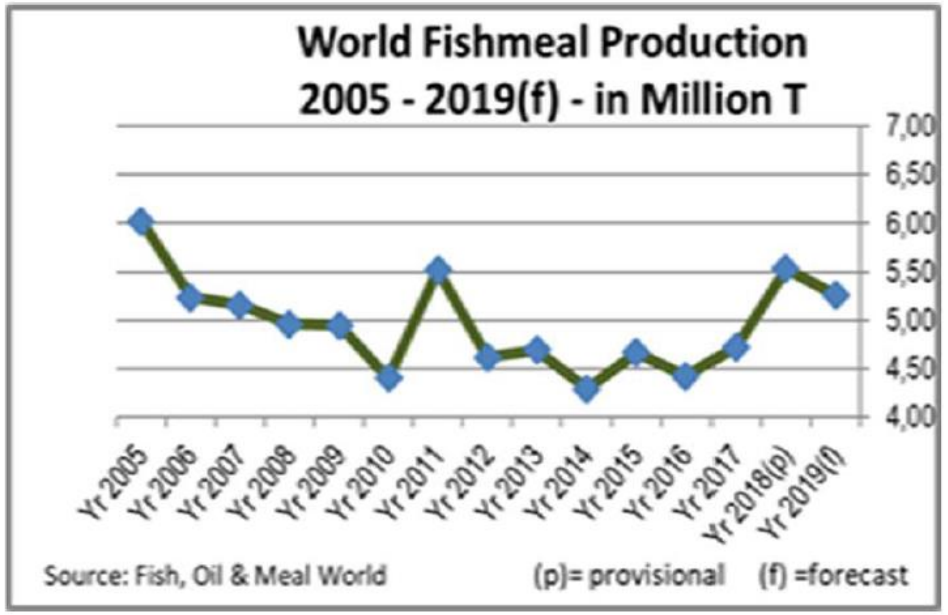


FAO (2020)

Fishmeal - an essential resource for aquaculture feeds



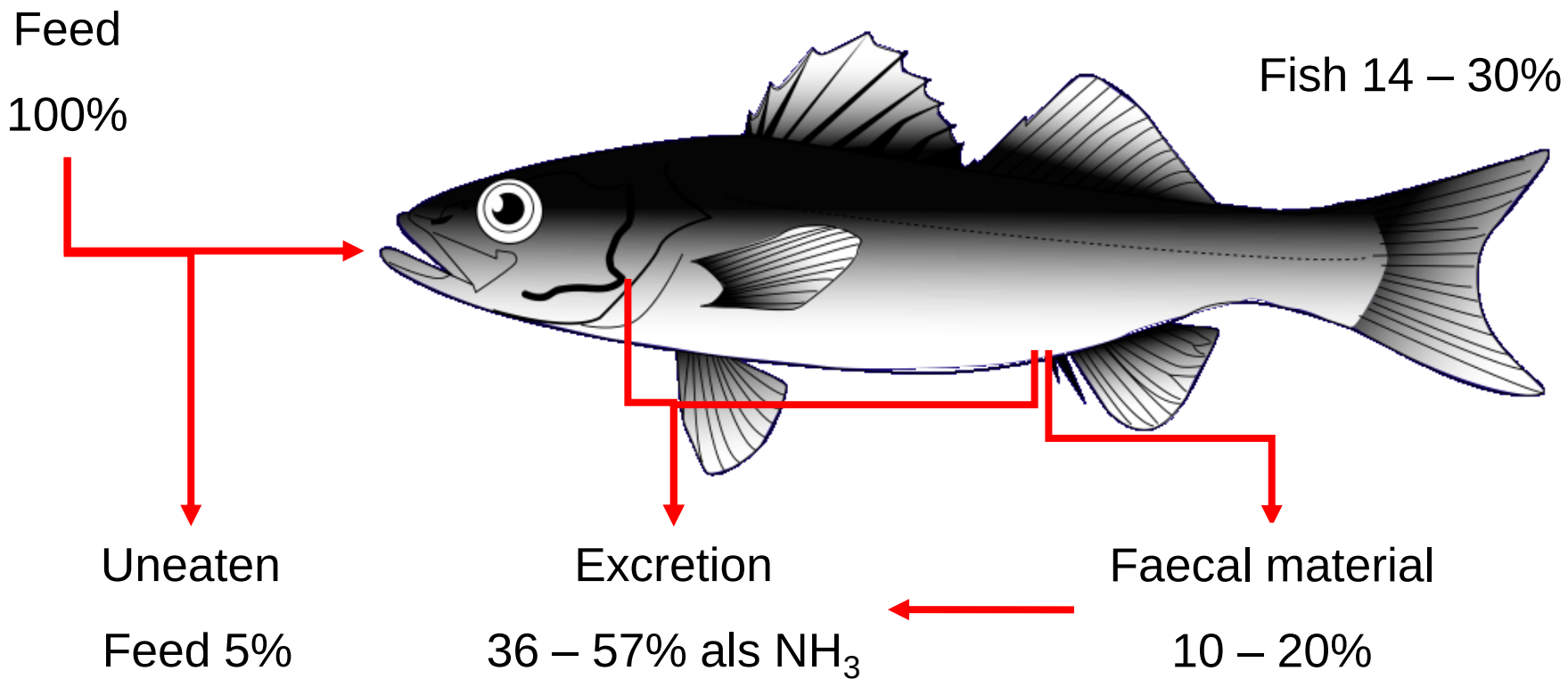
IFFO 2009



Fish, oil & meal world 2019

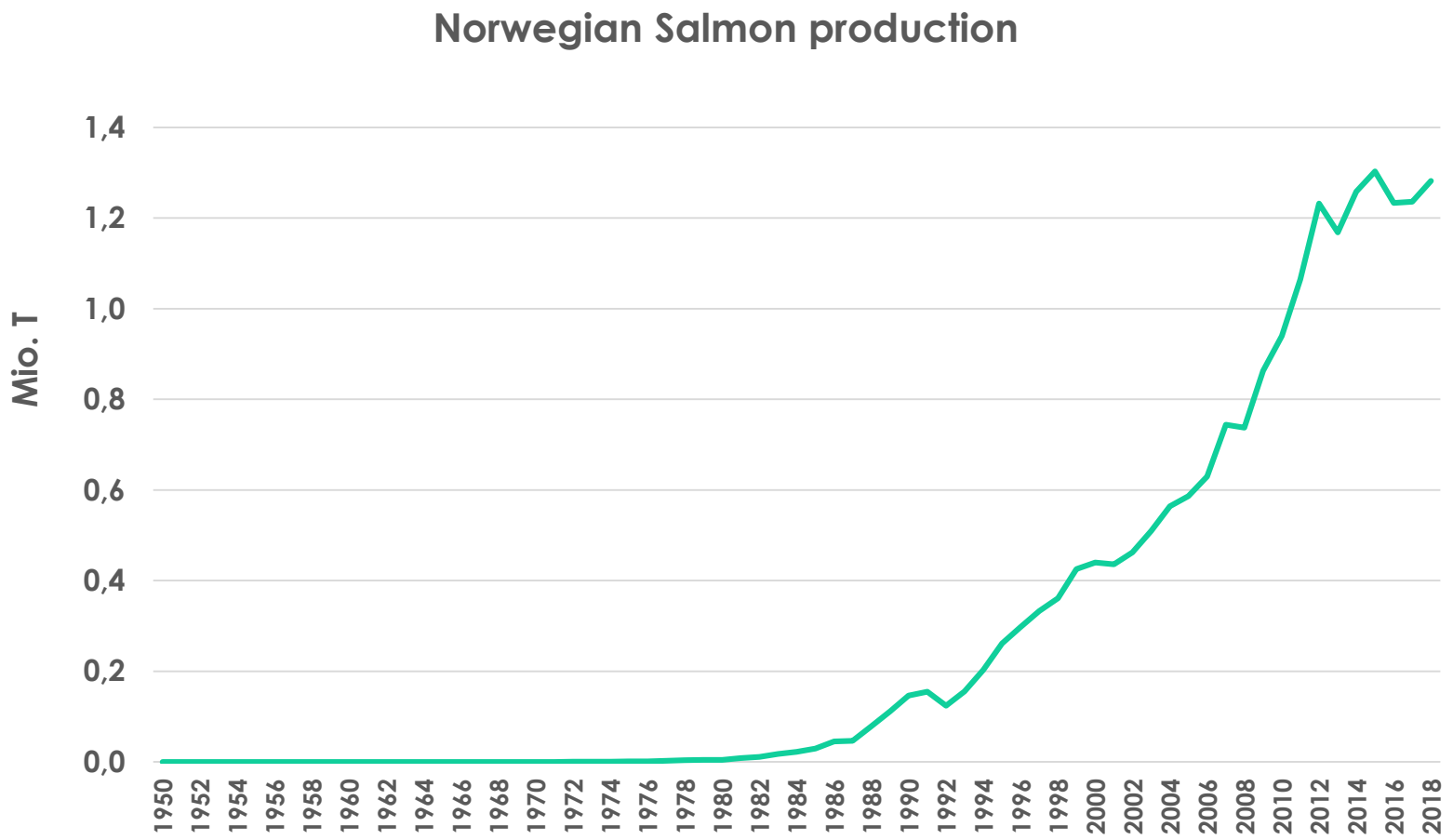
- Fishmeal will be a limited resource in the future, claimed by various users
- Fishmeal production can affect natural fish stocks
- However, limiting fishmeal quantities can also influence aquaculture development

Nutrient budget of a fish illustrated by nitrogen (N)



According to Schneider *et al.* 2005

Case study: Norwegian salmon production



FAO (2020)

Case study: Norwegian salmon production

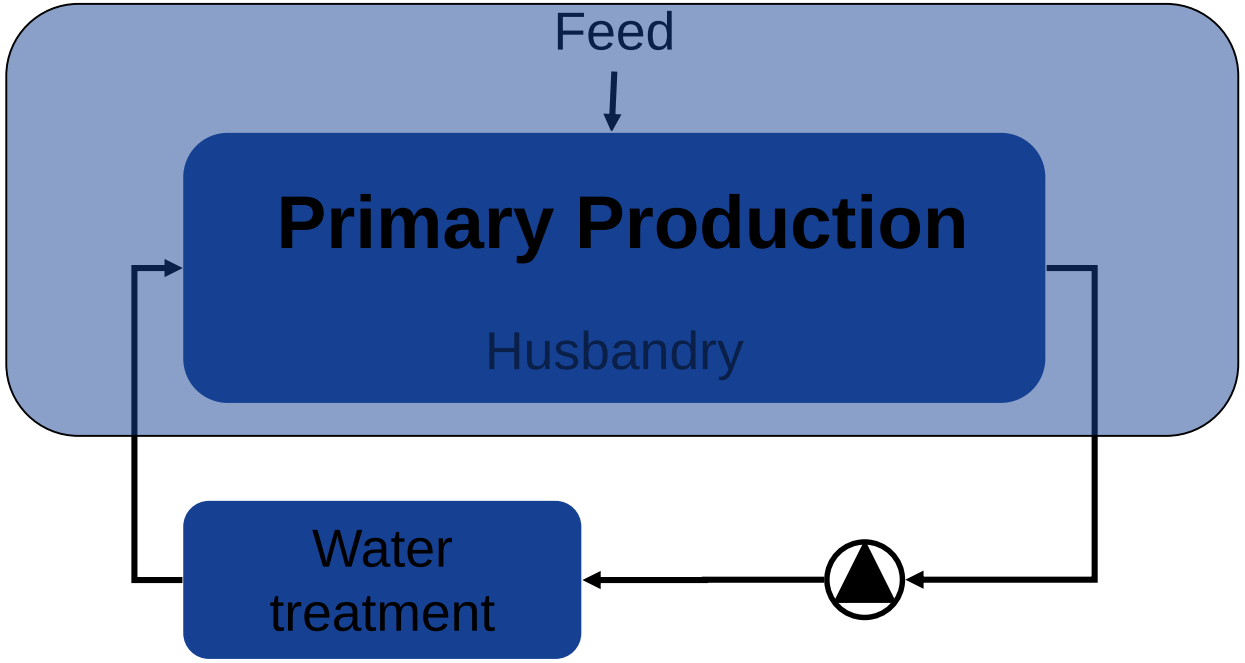
- Salmon production 2018: 1.28 million tonnes
- Total feed quantity 2018: 1.6 million tonnes
- Total solids 2018: 0.32 million tonnes (DW)
- Organic material 2018: 29 000 tonnes (DW)

www.ens-newswire.com

Conclusion:

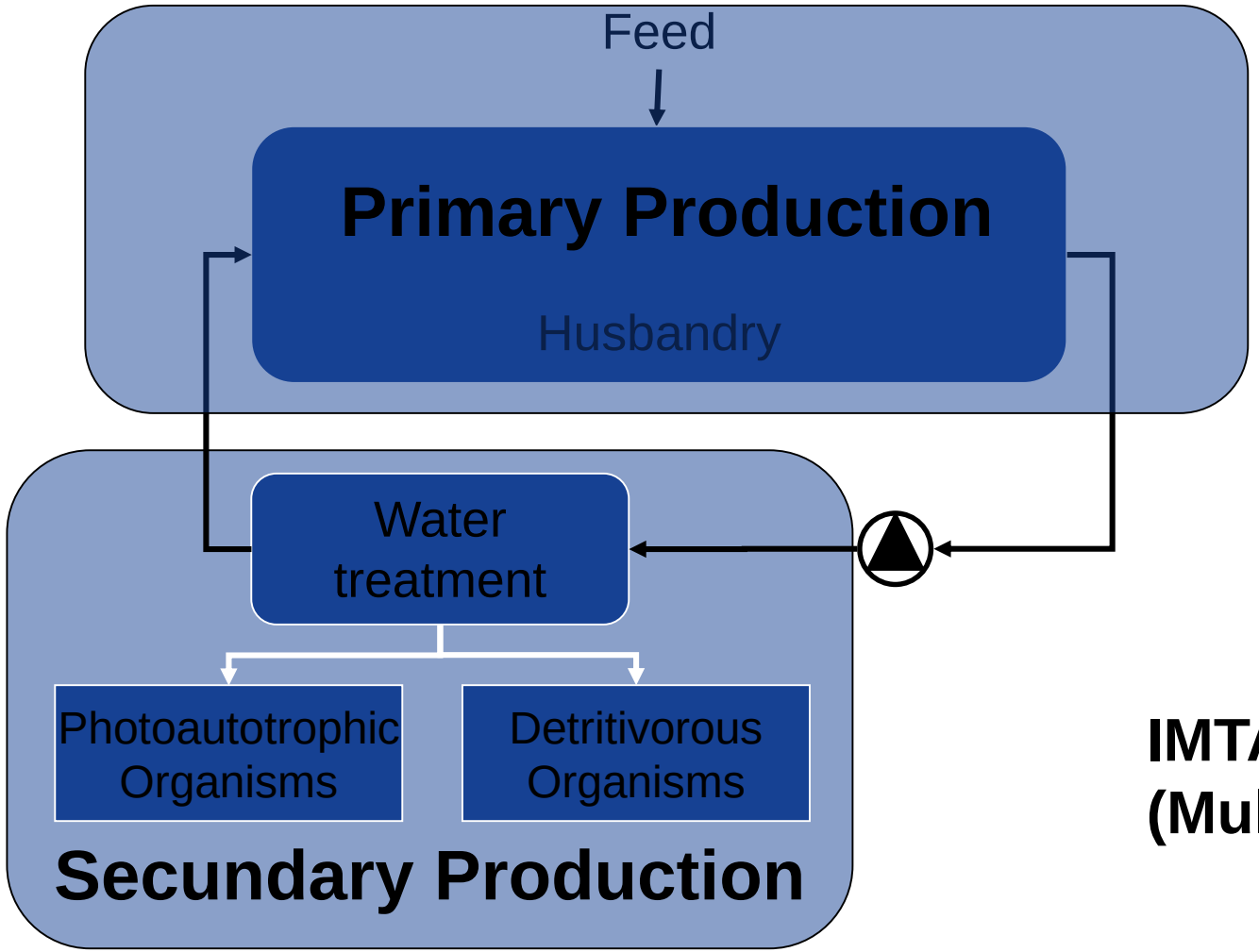
A high-quality "resource" is discarded unused and pollutes the surrounding environment of the aquaculture farms.

Aquaculture production in closed (recirculating) systems



Conventional Recirculating Aquaculture System (RAS)

Aquaculture production in closed (recirculating) systems



IMTA - Integrated MultiTrophic (Multiloop) Aquaculture

Why worms?

- Worms are found almost everywhere
- Represent a large fraction of the natural diet of many animals (birds, fish, small mammals, etc.) - suitable biochemical composition (e.g. amino & fatty acids)
- Short generation times and very broad food spectrum
- Agricultural soils - earthworms (Oligochaeta) up to 600 ind./m² (<300g/m²)
- Seabed - sea worms (Polychaeta) according to Scaps (2002) up to 5,000 ind./m² adults and up to 60,000 ind./m² with juveniles) (up to 39 g/m² in natural systems)

→ BUT: own investigations 500 - 1,200 g/m²

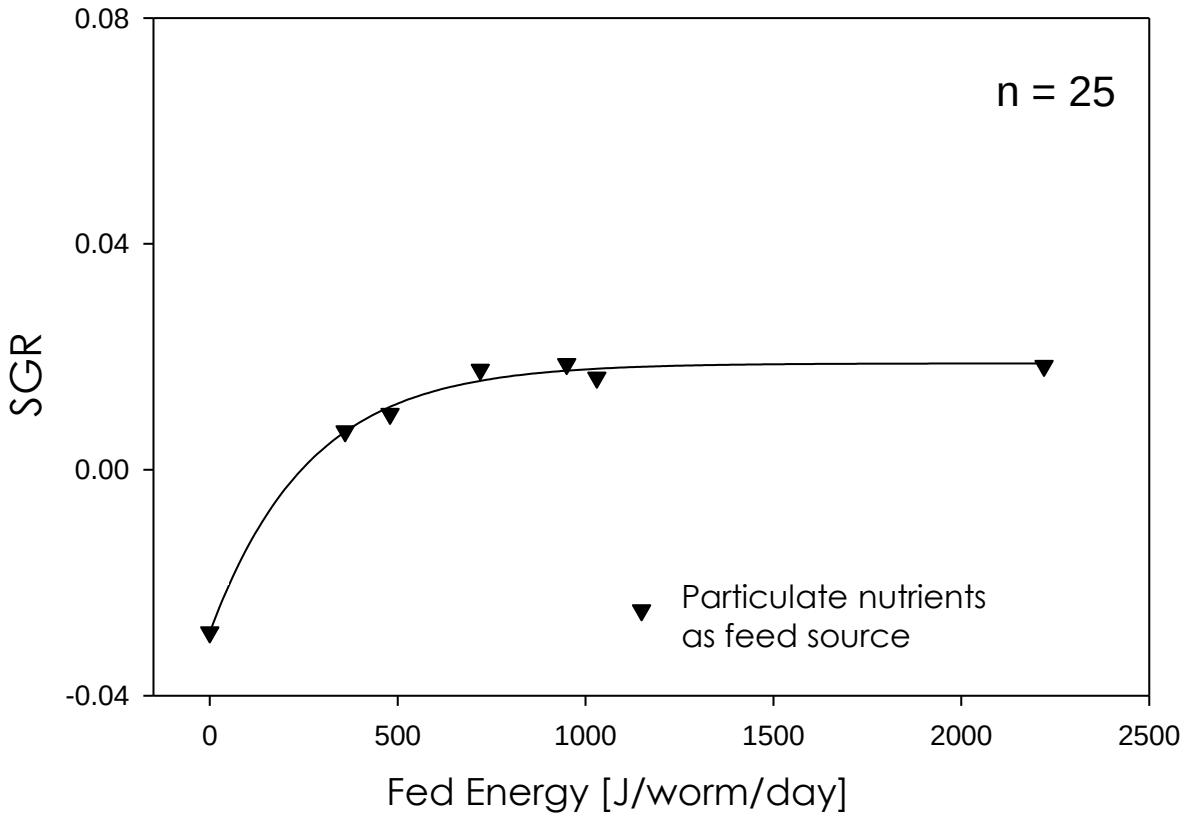
Investigations concerning the suitability of solid matter utilisation by *Hediste* (*Nereis*) *diversicolor* (O. F. Müller, 1776)

***Hediste (Nereis) diversicolor* / Common ragworm (Polychaeta)**

- Native species
- Variable feeding behaviour (planktivorous, carnivorous, detritivorous)
- Tolerant to temperature and salinity changes

→ **Important part of the natural diet of various fish and crustacean species**

Investigations concerning the suitability of solids utilisation by *H. diversicolor* (ZAFIRA / Bischoff 2003)



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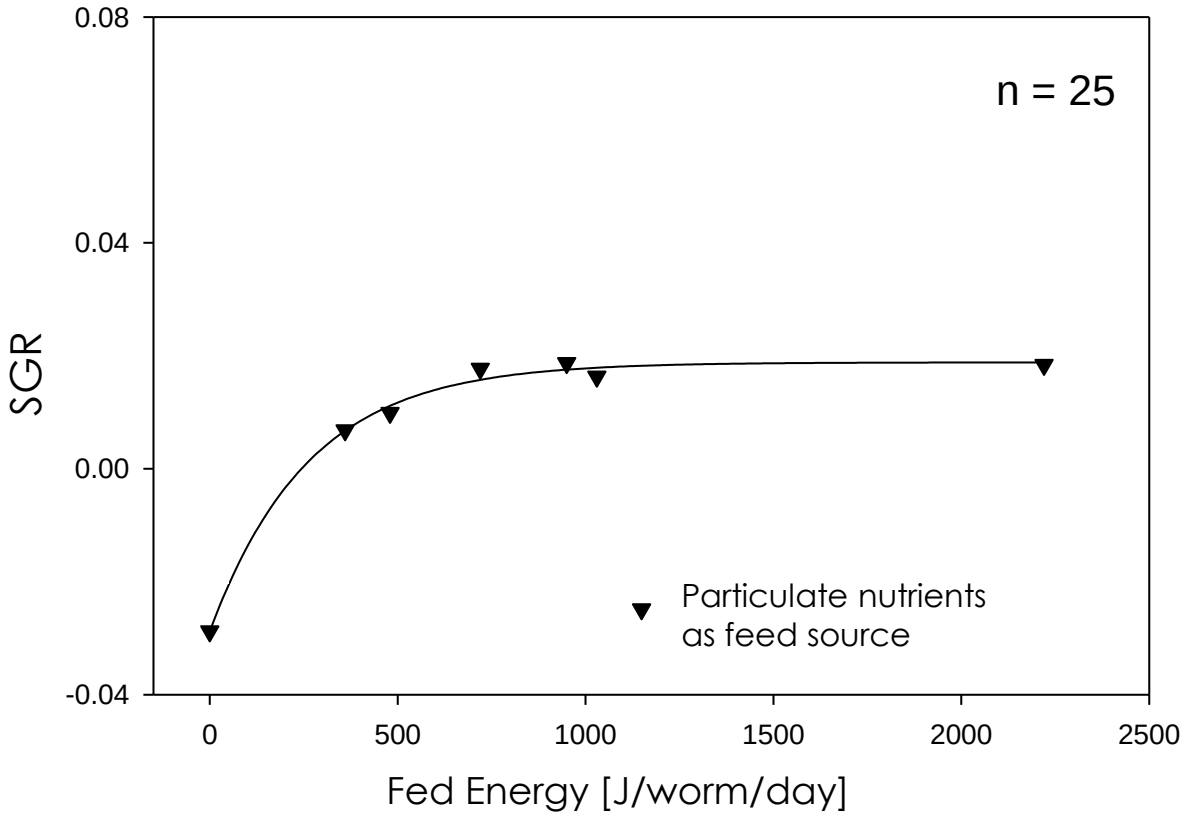

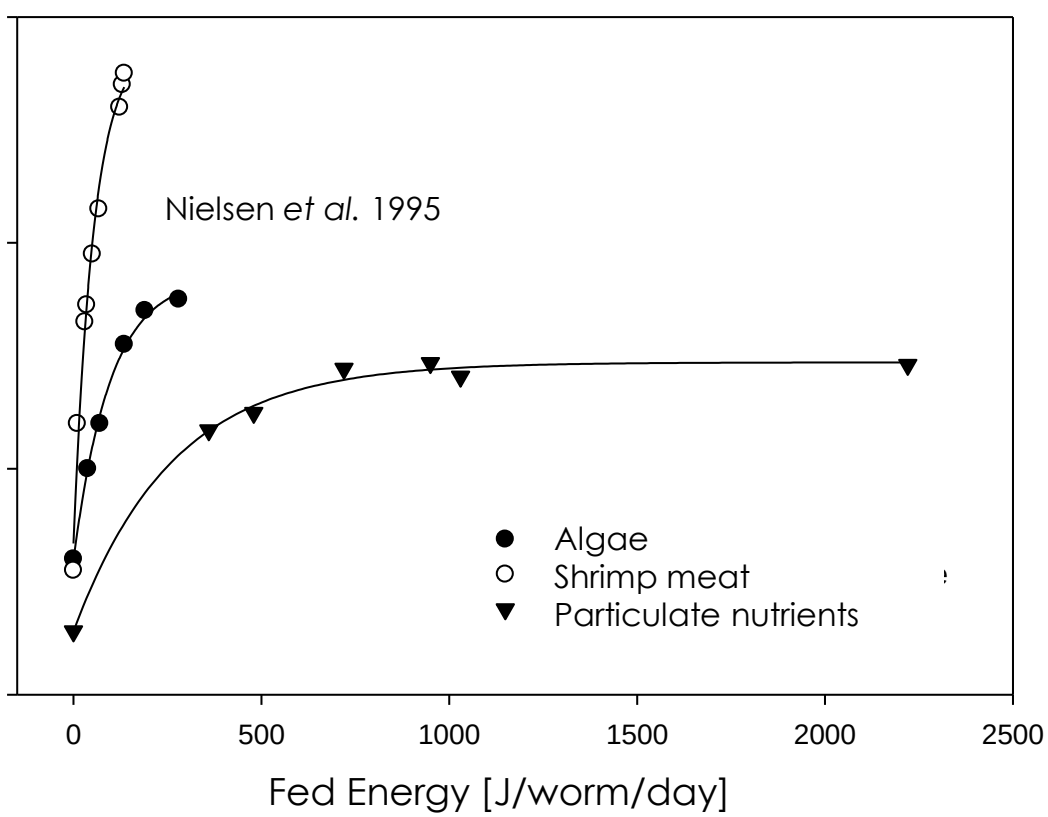

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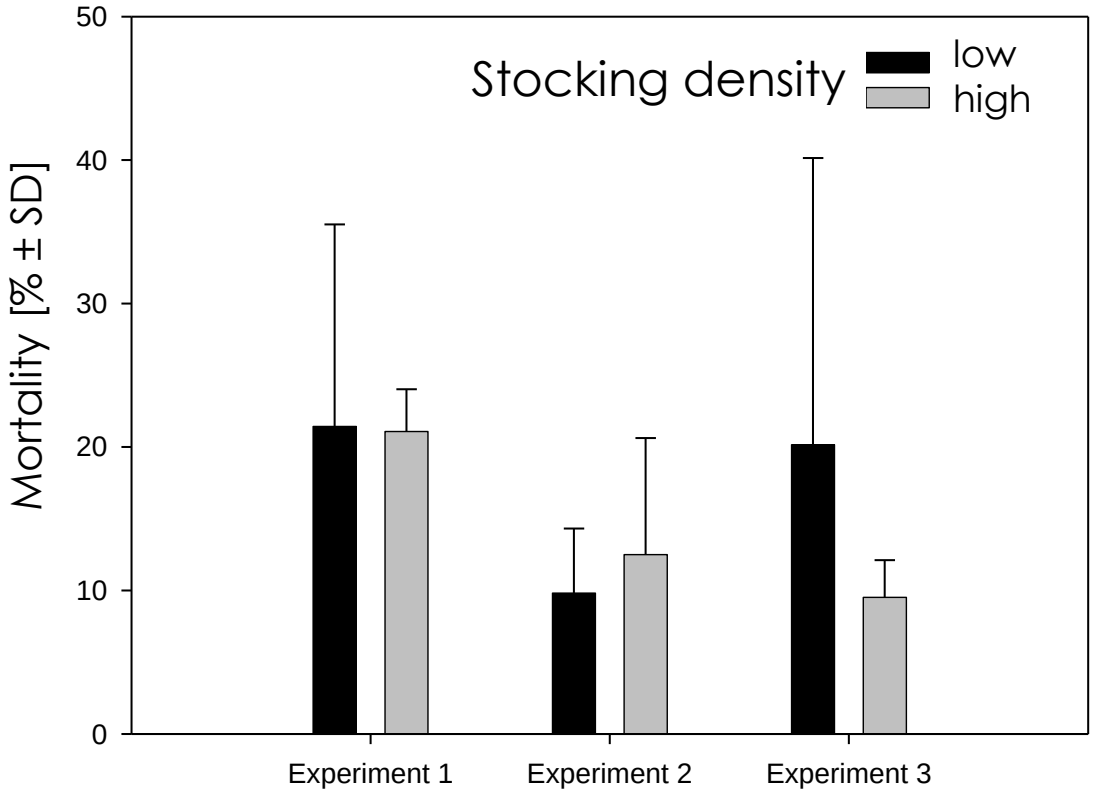
Investigations concerning the suitability of solids utilisation by *H. diversicolor* (ZAFIRA / Bischoff 2003)



+ **positive growth could be achieved**

- **growth is lower than described in the literature, but the feeds described had higher nutrient contents and more energy**

- **unsatisfactory mortality during the trials**

Research questions:

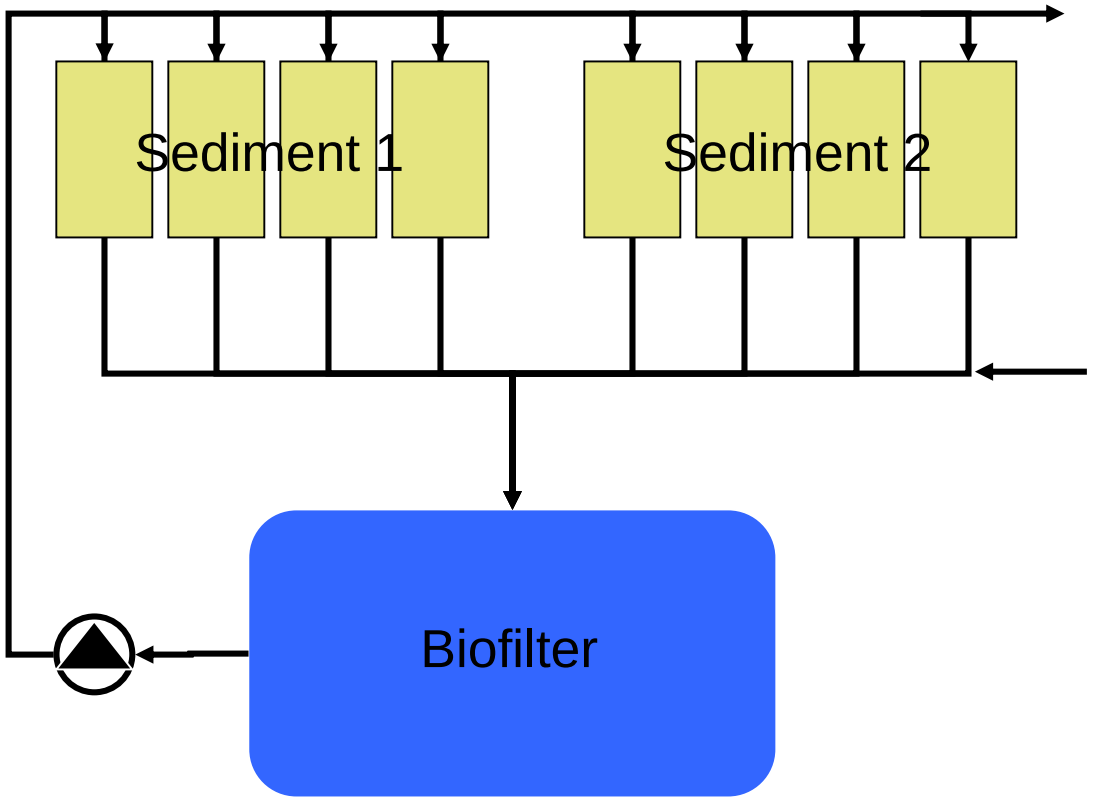
1. What are the biological requirements for the successful culture of detritivorous organisms?

2. Under which conditions is nutrient recycling by detritivorous organisms possible?

3. Is a reduction of solid waste possible through integrated aquaculture?

Impact of the sediment on *H. diversicolor*?

- Experimental setup (partial section)



Measurement of the

- **initial & final weights**
- **mortality**

Impact of the sediment on *H. diversicolor*?

Fine sand (grain size ≤ 2mm) Sediment 1 (Sed. 1)

Coarse sand (grain size 2 - 4mm) Sediment 2 (Sed. 2)

Ceramic bodies (Ø inside 5mm) Sediment 3 (Sed. 3)

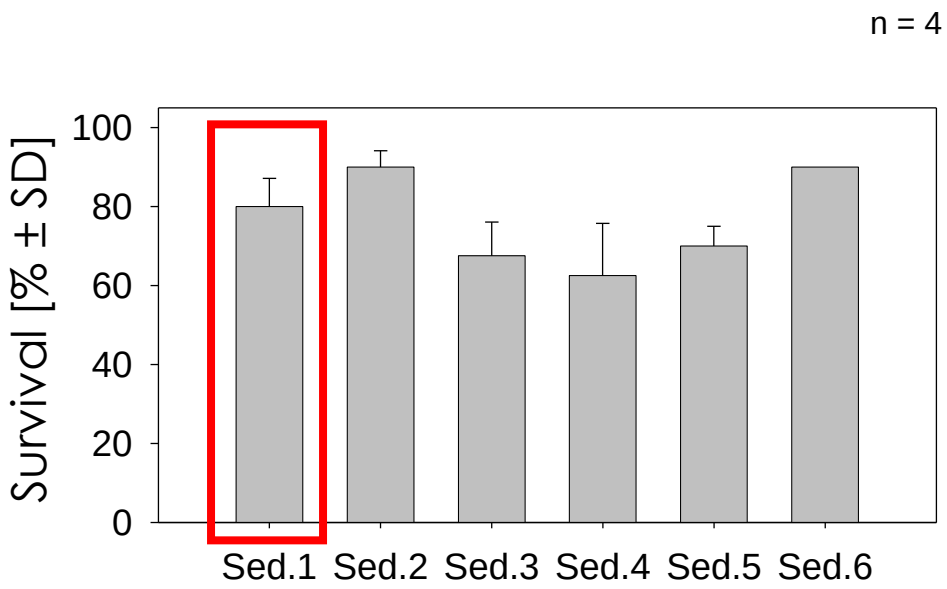
Without sediment Sediment 4 (sed. 4)

PVC doormat Sediment 5 (Sed. 5)

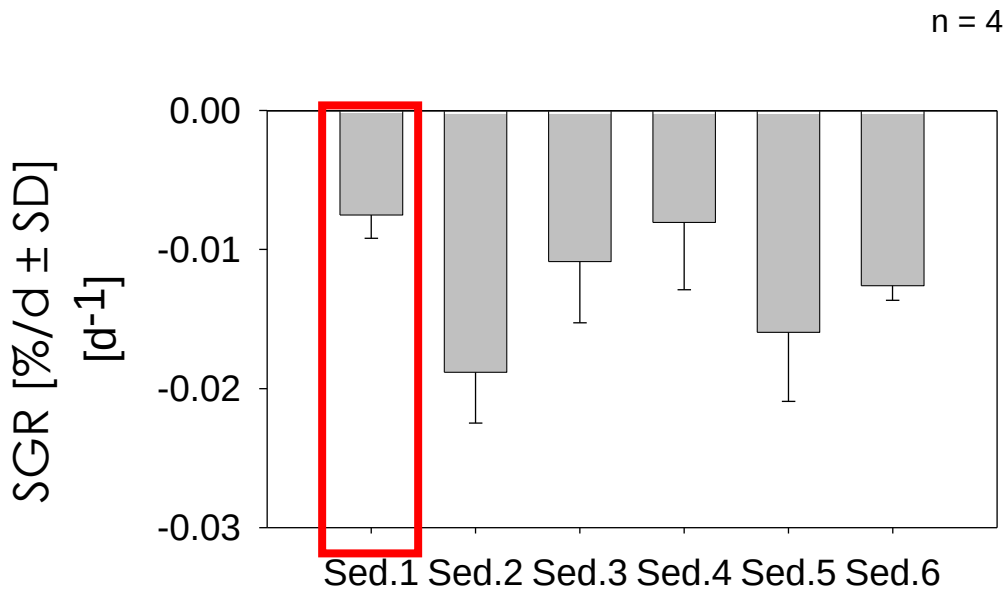
Aquaclay© (grain size ≤ 3mm) Sediment 6 (Sed. 6)

Impact of the sediment on *H. diversicolor*?

Survival



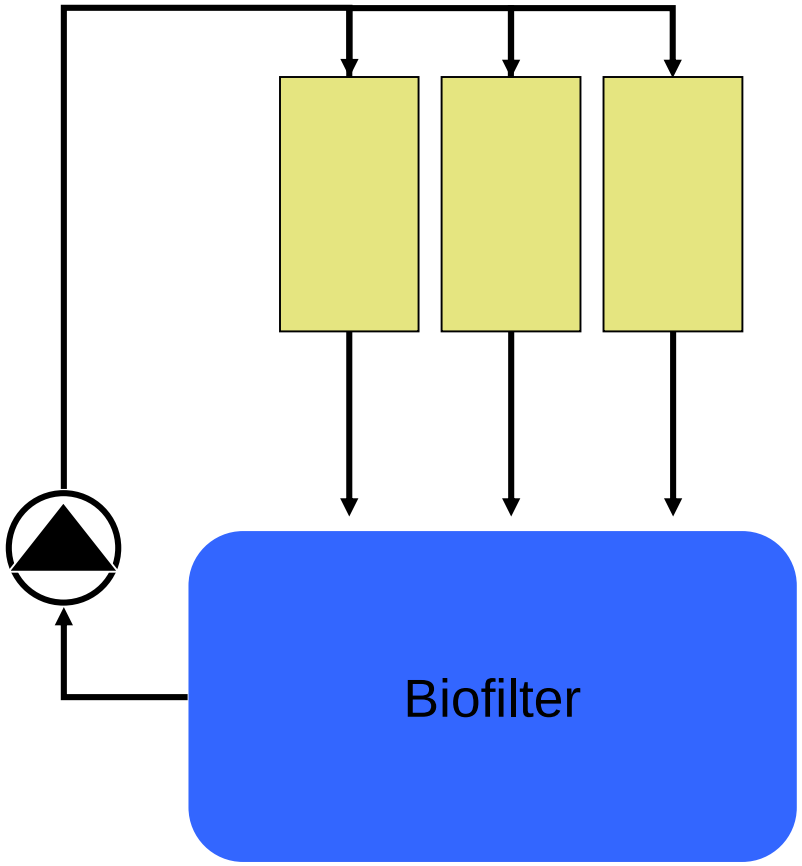
SGR (Specific Growth Rate)



→ **Fine sand (Sed.1) was selected as the most suitable sediment for all further experiments**

Under which conditions is the culture of *H. diversicolor* successful?

- Experimental setup



Measurement of the

- **mortality**
- **initial & final weights**
- **concentrations of dissolved nutrients**

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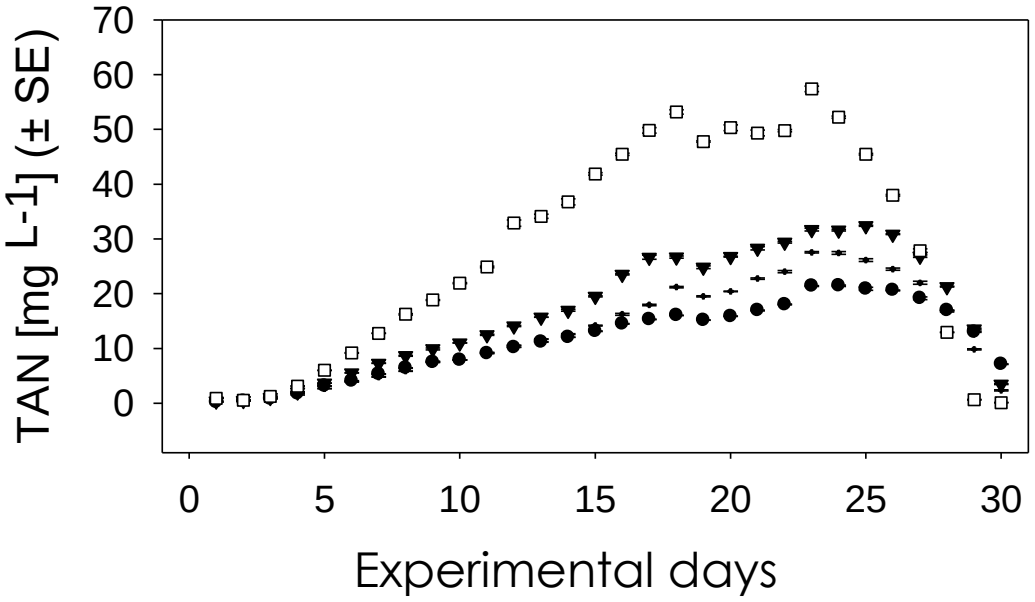
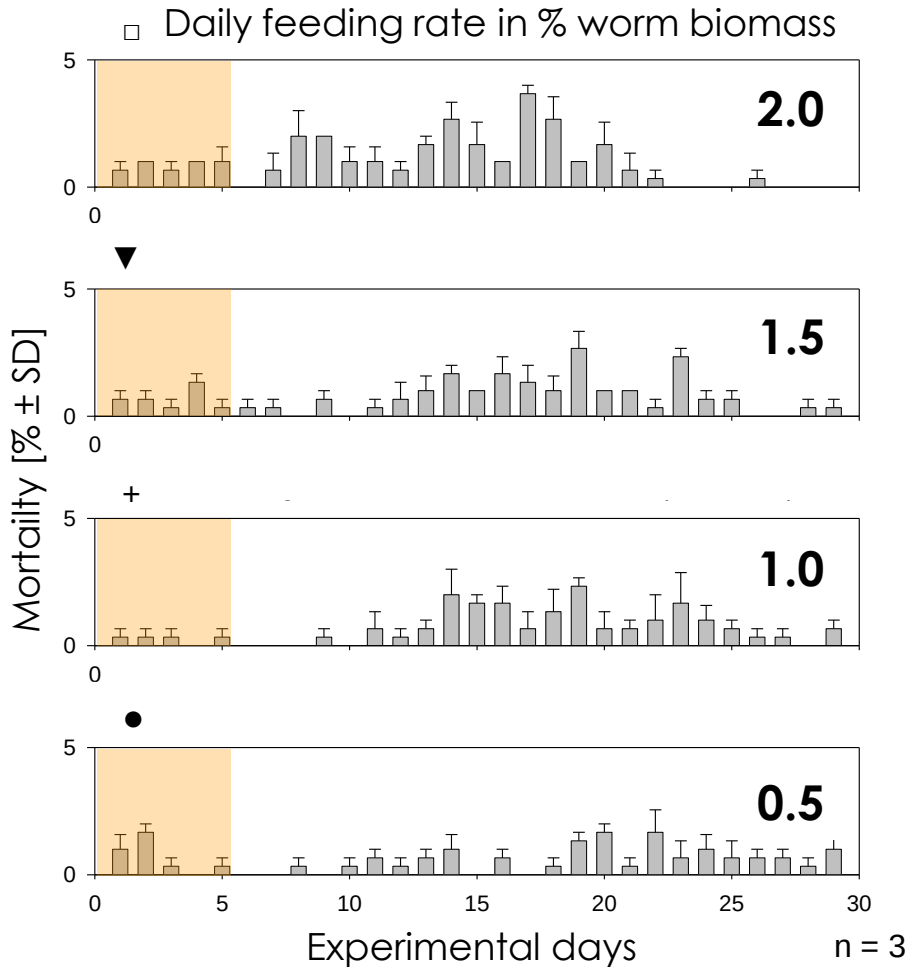
Under which conditions is the culture of *H. diversicolor* successful?

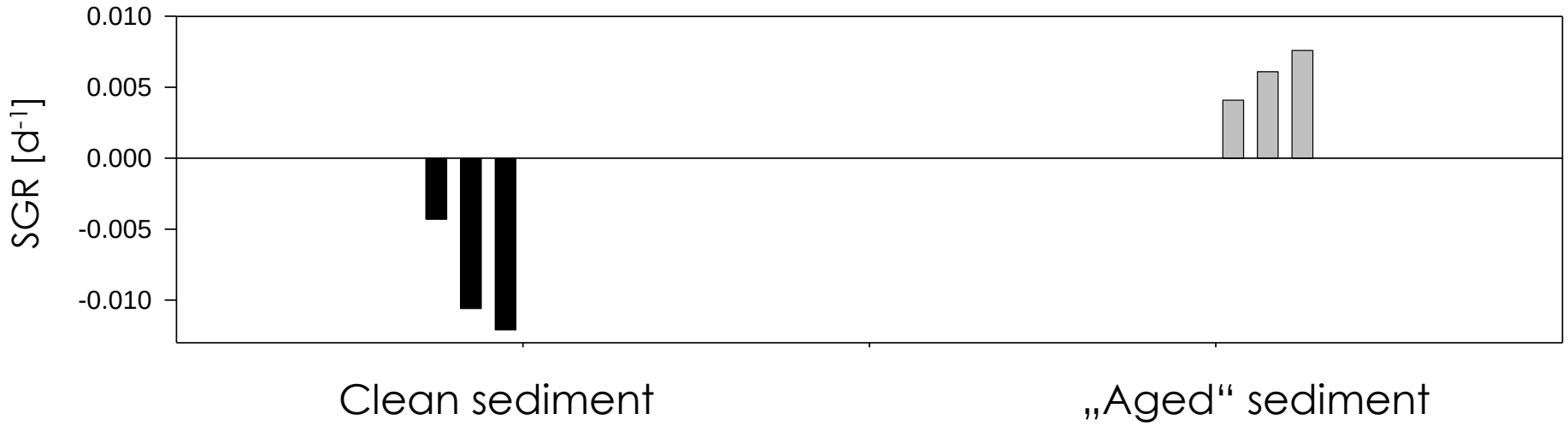
n = 3



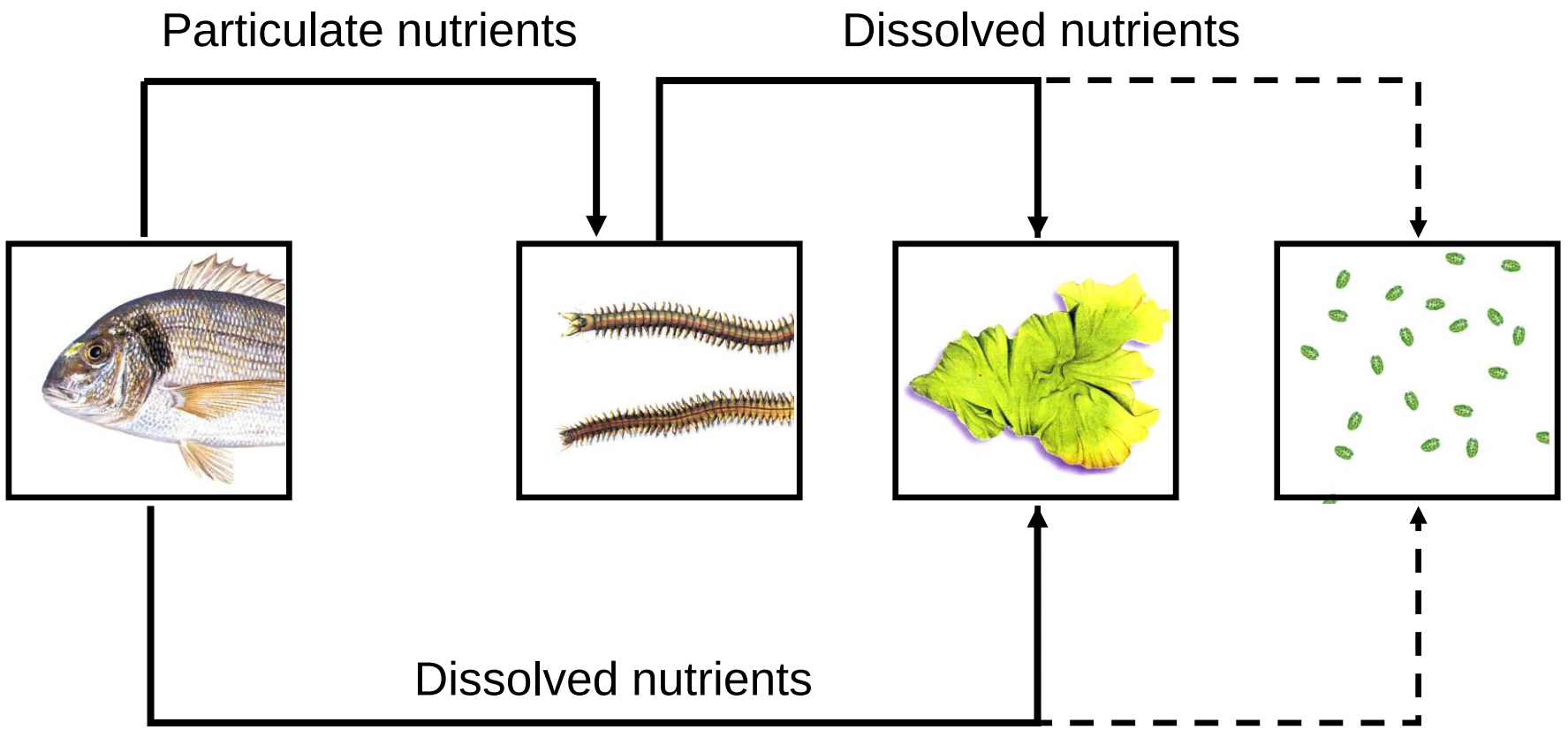


TAN concentrations strongly influence the survival of the worms!

Under which conditions is the culture of H. diversicolor successful?

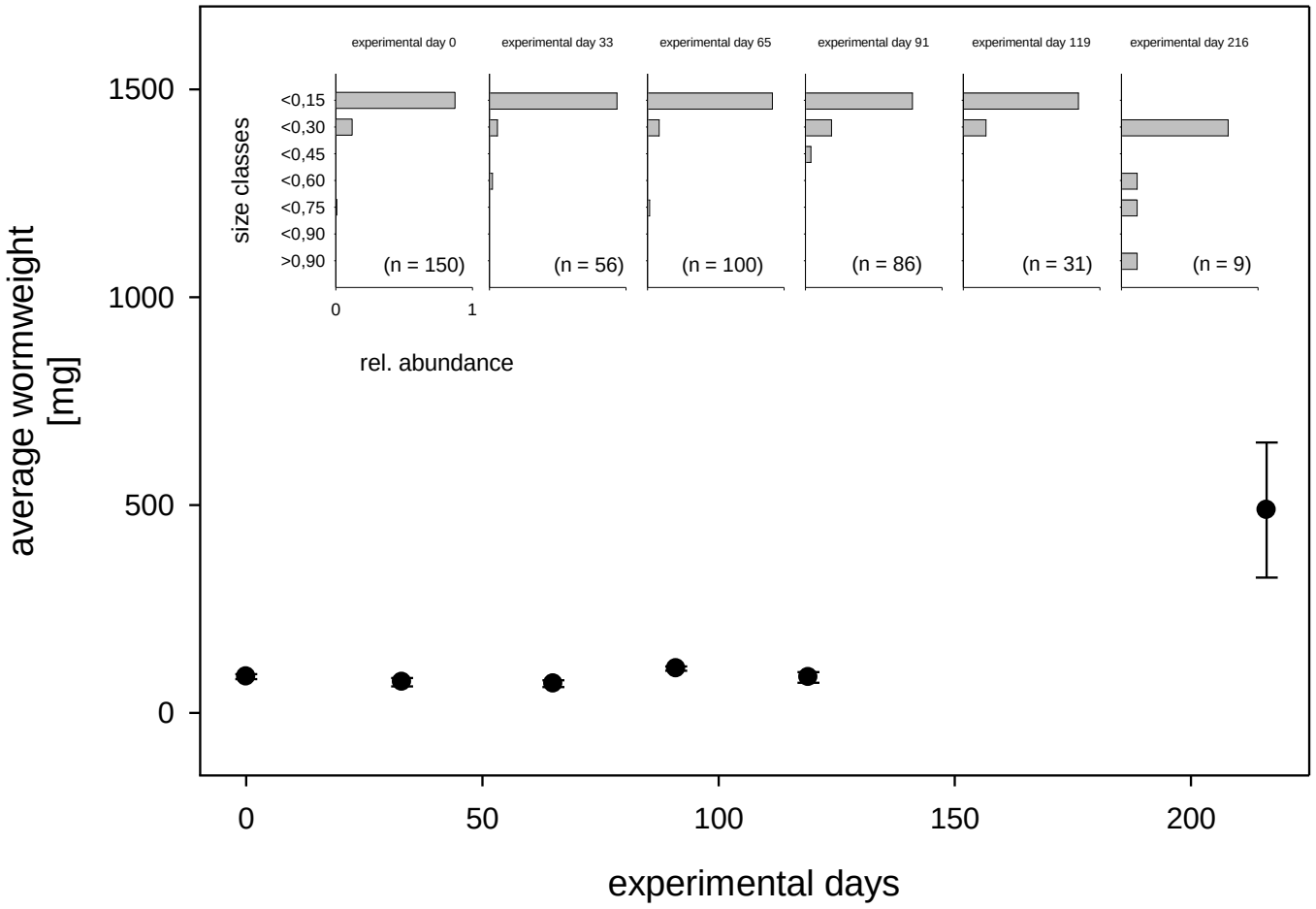


How does *H. diversicolor* perform in an integrated RAS?



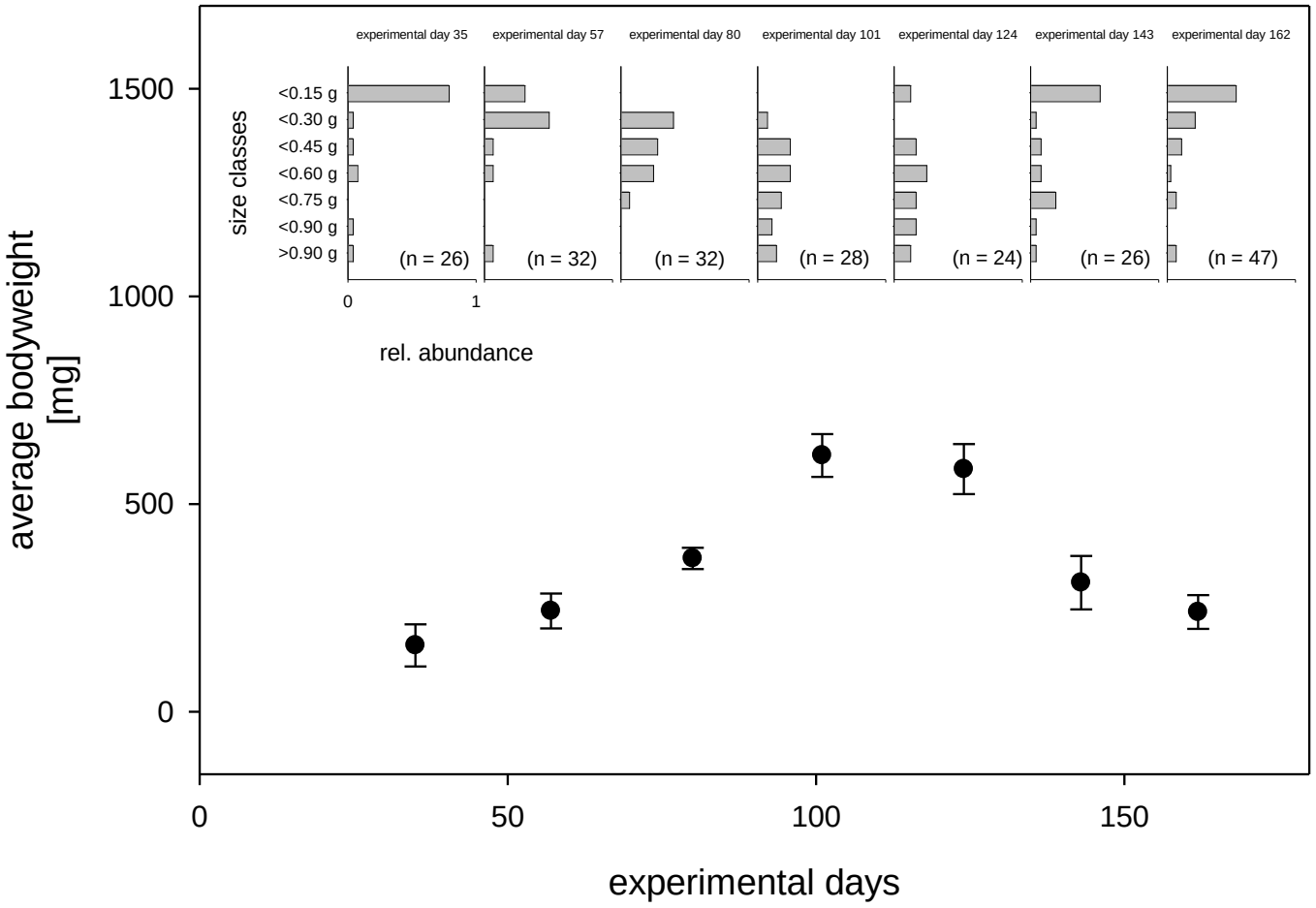
How does *H. diversicolor* perform in an integrated RAS?

- MARE I



How does *H. diversicolor* perform in an integrated RAS?

- MARE II



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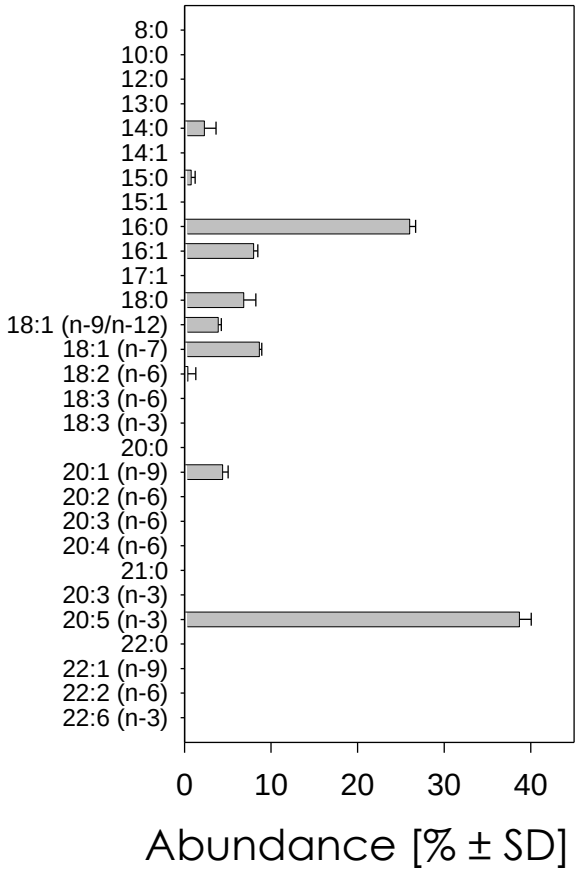
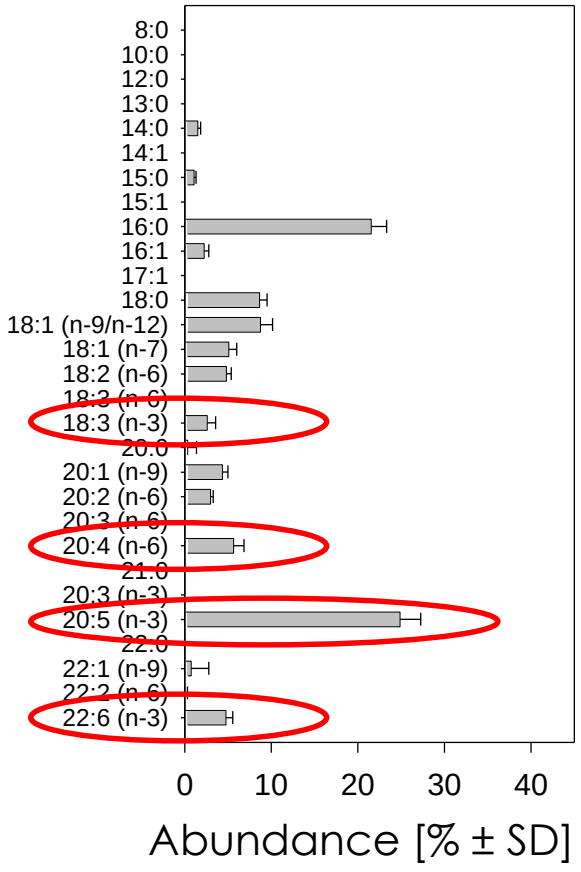
Does the production in the integrated system influence the composition of the fatty acids of *H. diversicolor*?





Conclusion 1:

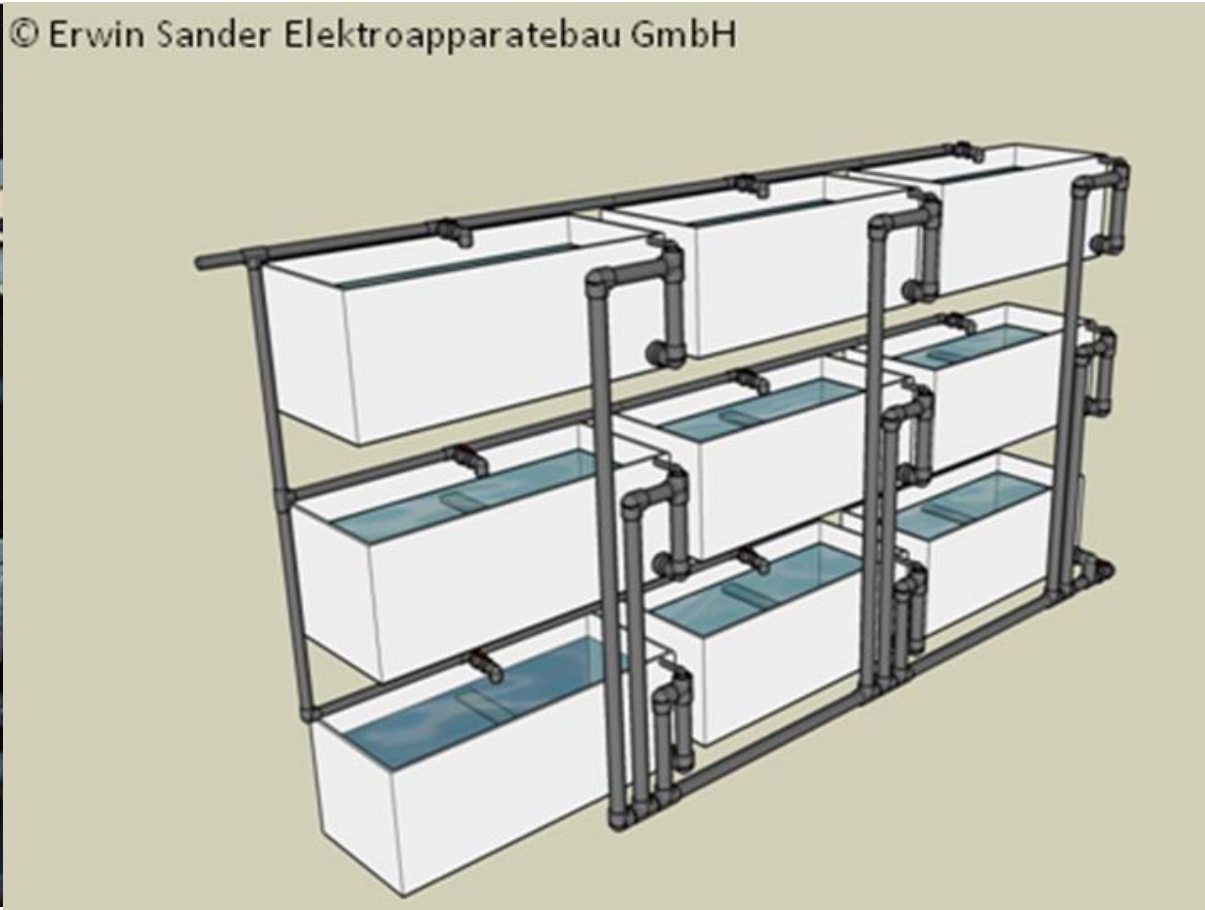
- **Polychaetes are suitable for IMTA production, thus increasing the nutrient efficiency of the system**

- ***Hediste diversicolor* is able to selectively enrich fatty acids or to re-synthesise them by itself**

Project IntAPol – Integrated Aquaculture of Polychaetes

- Saltwater recirculation system for European sea bass (*Dicentrachus labrax*) on the southern edge of the Lüneburger Heide
- Solids removal via 2 drum filters (faeces of the fish = solids 1 and excess bacterial biomass of the biofilter = solids 2).

Project IntAPol – Integrated Aquaculture of Polychaetes



- Rag system close to the production

Project IntAPol – Integrated Aquaculture of Polychaetes

- The experiment was successful (including positive growth)
- Amino acid profile of the worm groups

Amino Acid	Initial values	Solids 1	Solids 2
Asparagine (asp)	54 (± 1,32)	64 (± 3,35)	63 (± 1,39)
Glutamic acid (glu)	76 (± 1,39)	89 (± 4,66)	90 (± 1,86)
Serine (ser)	24 (± 0,62)	29 (± 1,51)	29 (± 0,75)
Threonine (thr)	16 (± 0,80)	24 (± 0,83)	23 (± 0,55)
Histidine (his)	11 (± 0,50)	14 (± 0,66)	14 (± 0,54)
Glycine (gly)	29 (± 0,96)	38 (± 2,53)	37 (± 1,30)
Arginine (arg)	31 (± 0,51)	39 (± 3,08)	40 (± 1,21)
Alanine (ala)	35 (± 0,76)	40 (± 2,13)	42 (± 1,03)
Tyrosine (tyr)	18 (± 0,45)	22 (± 1,19)	23 (± 0,83)
Valine (val)	25 (± 0,50)	31 (± 1,32)	34 (± 1,29)
Methionine (met)	10 (± 0,28)	12 (± 0,93)	13 (± 0,33)
Tryptophan (trp)	30 (± 0,64)	38 (± 1,47)	42 (± 1,55)
Phenylalanine (phe)	22 (± 0,52)	27 (± 1,12)	28 (± 1,03)
Leucine (leu)	28 (± 0,68)	34 (± 1,49)	36 (± 1,10)

Conclusion 2:

- **Nitrogen content of worm biomass increases during feeding with solids from an aquaculture recirculation system**

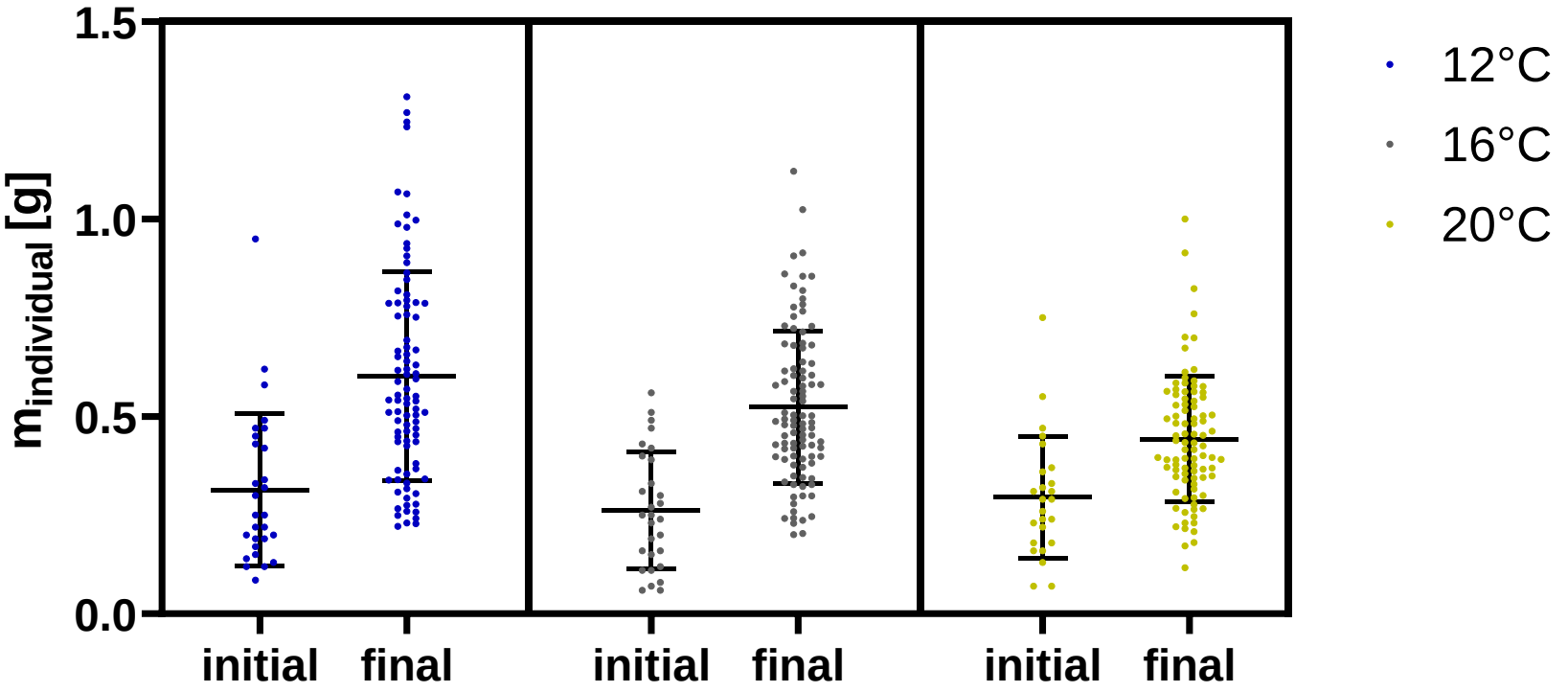
- **Amino acid spectrum improves during feeding with solids from an aquaculture recirculation system**

Master thesis Philipp Sandmann (2018): Utilization of sediments from the culture of African Catfish (*Clarias gariepinus*) for cultivating the Polychaete *Hediste diversicolor* (Müller, 1776)

- Special characteristics of this work:
  - Culture of a marine polychaete with solids from freshwater aquaculture
    - Transferability of the principle (?)
    - Avoiding the transfer of potential pathogens

- African catfish is considered to be a very good nutrient utiliser, especially nitrogen, and the solids are therefore classified as "nutrient-poor"

- Master thesis Philipp Sandmann (2018)
- Positive growth and biomass increase during the experimental phase (temperature effect ?)



- Master thesis Philipp Sandmann (2018)
- Specific Growth Rates (SGR)

	System A (12°C)	System B (16°C)	System C (20°C)
Replicat 1	2.38 %	2.66 %	1.58 %
Replicat 2	2.73 %	2.20 %	1.53 %
Replicat 3	2.32 %	2.27 %	1.28 %
Mean±SD	**2.48 ± 0.18% [a]**	**2.38 ± 0.20% [a]**	**1.46 ±0.13 % [b]**

Conclusion 3:

- **Feeding *Hediste diversi*color with solids from freshwater aquaculture is possible and successful**
- **Feed quality does not influence the growth and survival rate of *Hediste diversicolor* to the extent suspected**
- **Unfortunately, the effects of temperature on gamete maturation and somatic growth could not be clearly explained**

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Master thesis Sven-Ole Meiske (2021): Suitability of nutrient recovery from particulate nutrients of a commercial trout pond system (*Oncorynchus mykiss* Walbaum, 1792) using vermifiltration

- Evaluation of the potential of *Eisenia fetida* (Bouché, 1972) for further utilisation of solids from aquaculture
- Verification of the fate of heavy metals present in the culture of *Eisenia fetida*
- Evaluation of the compost produced

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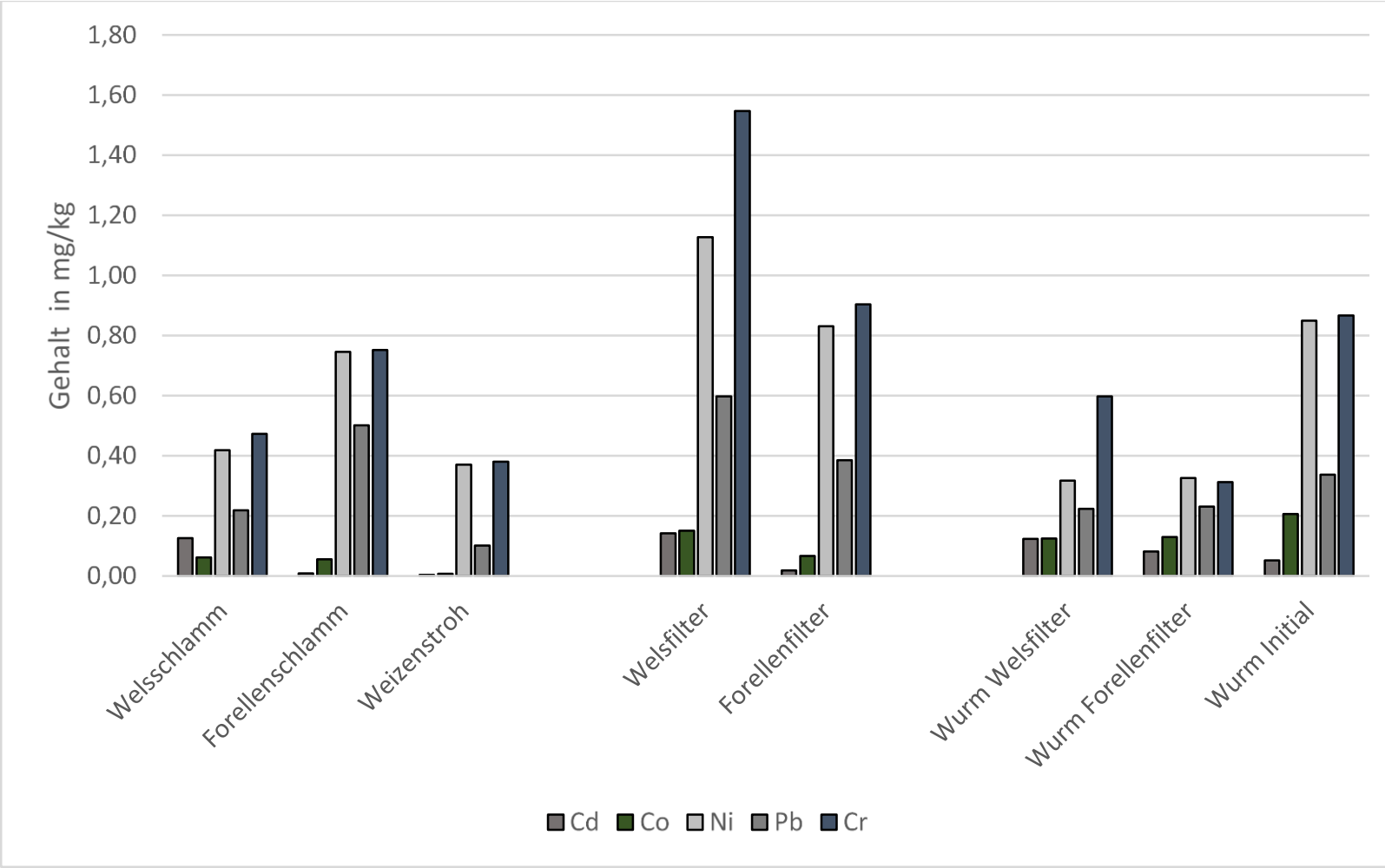
Master thesis Meiske (2021)



Comparative analysis of the heavy metals Cd, Co, Ni, Pb & Cr …

Conclusion 4:

- **Feeding *Eisenia fetida* with solid excreta from freshwater aquaculture is possible and can be successful**
- **Feed quality influences the growth, survival rate and reproductive potential of *Eisenia fetida***
- **The cultured worms accumulate some heavy metals according to the feed supply (Co & Cd), but others to a lesser extent (Ni, Pb & Cr)**

Final conclusions:

- Culture of detritivorous organisms - with regular reproductive events - is possible, culture conditions described
- Nutrient recycling through the culture of detritivorous organisms is possible; high-quality and healthy raw materials, as alternatives for future animal feed, can be produced through integrated aquaculture
- The bioreactors for the cultivation of *Hediste* (*Nereis*) *diversicolor* as well as *Eisenia fetida* can be used as additional biological filters to stabilize or improve water quality

BUT (so far):

- Implementing the production of worms in integrated aquaculture systems in accordance with

  - **EU regulation 178/2002 „food law & safety“**
  - **EU regulation 183/2005 „feed hygiene“**
  - **EU regulation 767/2009 „placing on the market and use of feed“**
  - **EU regulation 68/2013 „catalogue of feed materials“**

is (theoretically) only possible with substantial administrative effort.

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Thanks to the

- Aquaculture & Sea-Ranching team at Rostock University
- Mariculture Working Group at Institute for Marine Sciences in Kiel
- Department Marine Aquaculture at the Institute for Marine Resources in Bremerhaven

and (of course) your attention

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