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Faculty of Fisheries and Protection of Waters

Jihočeská univerzita v Českých Budějovicích
University of South Bohemia in České Budějovice
Czech Republic

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Intensification by simplification - recirculating hatchery and possible use of constructed wetland to increase production

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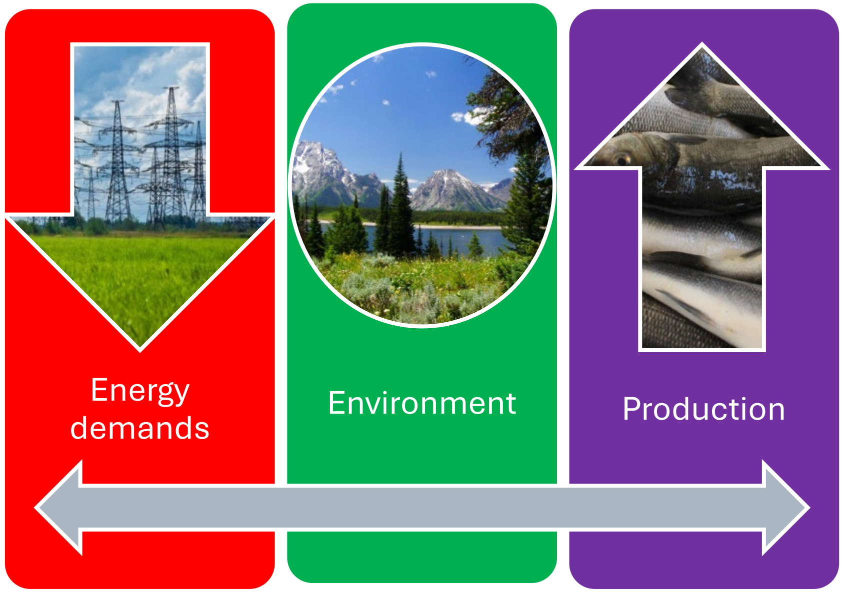
Introduction

- **Aquaculture intensification within a context of climate change**
  - new technologies
    - = high production, low water demand, low waste → RAS
    - = increase of initial investment and high energy demands
  - economic feasibility vs. environmental sustainability
- **Hatcheries for salmonids**
  - usually linked to headwaters or to spring water supply
  - sources more problematic – quantity, quality, diseases, year-round variability



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Introduction

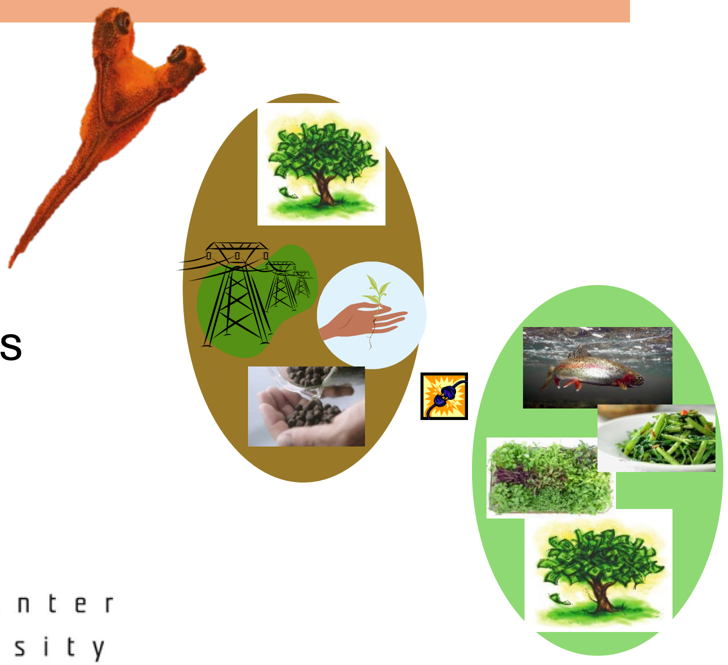
- **RAS hatchery can reduce**
  - water demand, disease transfer, impact on environment
  - usually with specialized technologies (microsieves, ozonization, UV sterilization) → ***raised energy demand and initial investments***

ARE THEY NECESSARY?

- **Way of simplification**
  - transformation of existing facilities to simple RAS
  - the use of available space for wetlands / aquaponics

GOALS:

- Keep **profitable** results with simple construction and low operation costs
- Make it **more profitable** by simple, small constructed wetland



Original conditions – how were they improved?

- Small old hatchery for brown trout and grayling (incubation apparates + trays)
- Connected with cellar – in total ~ 65 m^2
- Water source from adjacent river
- Old equipment available
- Small water borehole in the proximity
- Sharp minds + nifty hands

effective fingerling source for RAS farm

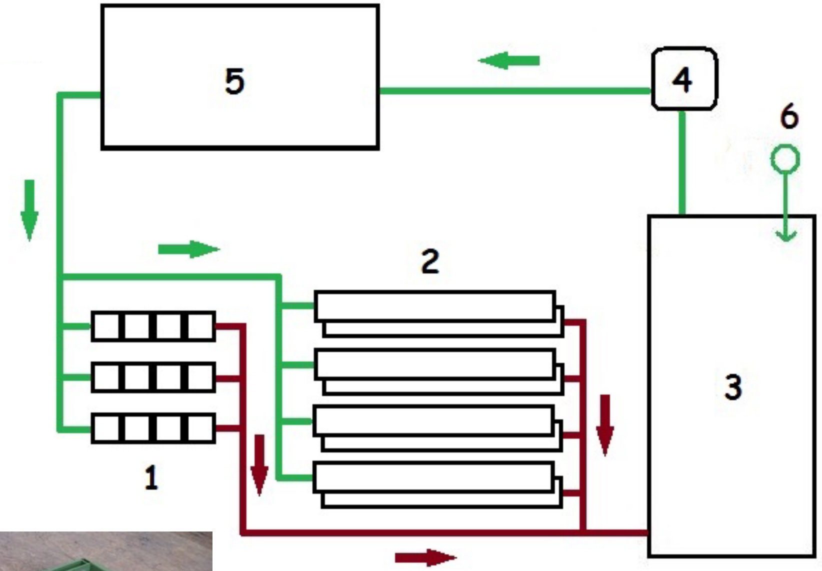
- Add pumps, pipes, circular tanks, biofilters, retention tanks
- All together around 8 000 €

The RAS hatchery for salmonids

- Two independent systems – incubation/nursery and rearing
- overall power/ water consumption 1.6 kWh and 0.05 l sec^{-1}

The 'nursery' system (in total ~3.8 m^3 excluding piping)

- egg incubation, hatching, and rearing till the weight of 0.4 - 0.5 g
- 12 incubation apparats (~0.02 m^3) and 8 trays (~0.16 m^3)
- retention tank (1 m^3)
- sedimentation tank (1.2 m^3) with two Bioblocs
- circulation pump (0.55 kWh)
- fresh water demand ~0.01 l sec^{-1}(compensation of evaporation and cleaning)



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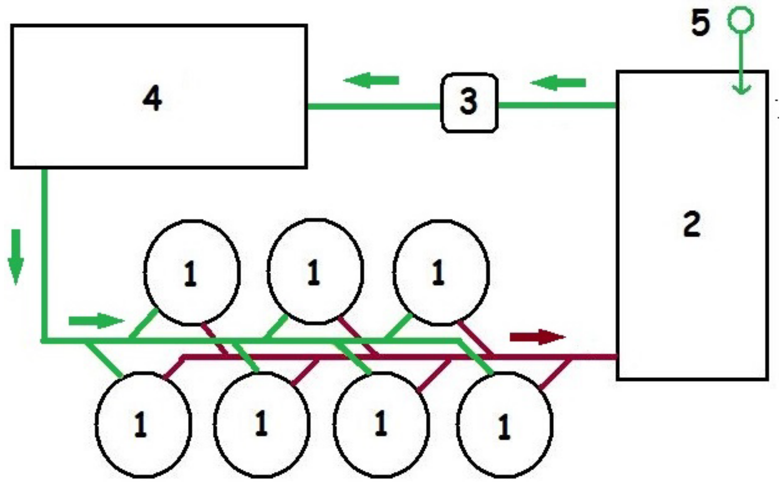
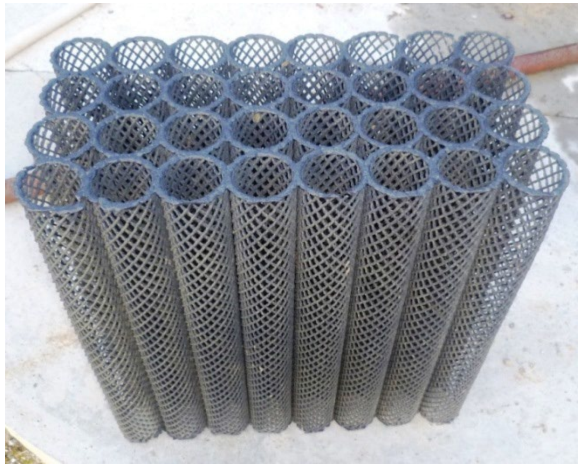
The RAS hatchery for salmonids

The 'rearing' system for (in total ~10.6 m^3 excluding piping)

- rearing of fish from 0.4-0.5 g to 2 g (4 g)
- 7 circular tanks (~0.7 m^3)
- biofiltration/sedimentation unit (~2.2 m^3) with 12 Bioblocs
- one retention tank (~3.5 m^3)
- circulation pump (0.75 kWh)
- fresh water demand ~0.04 l sec^{-1}(compensation of evaporation and losses during cleaning)





How it worked?

- 80,000 eyed eggs per production cycle (from certified disease-free farms)
- 11 production cycles done during 2.5 years
- t, O_2, pH – daily, chemical analysis bi-weekly
- Normal hatchery practice (removing dead individuals, egg shells, sludge – regularly)
- 3 days post-hatching, larvae moved to trays, after absorption of the majority of yolk, feeding of the freely floating fry initiated
- initial feeing *in excess* to trigger foraging activity, later *ad libitum*
- Trays cleaned once or twice daily for faeces, uneaten feed, and dead individuals

How it worked?

- Fish fry moved to the rearing system when reached weight of 0.45-0.50 g.
- Daily feed ration 2.5-5.5% of fish biomass, according to temperature, fish size, and appetite
- Circular tanks cleaned regularly for faeces and dead individuals
- The biofiltration/sedimentation tank cleaned every second day
- The water flow regulated by ball valves according to the size of fish and biomass
- After each production cycle, both systems were sanitazed
- **Fish growth and feed conversion monitored bi-weekly**

$FCR = w_k / w_p$ (w_k=amount of feed (kg) and w_p= weight increment (kg))

How it worked?

- Oxygen saturation > 85% (inlet) and > 75% (outlet)
- Production cycle shorter than 3 months
- Highest losses during the initial feeding (mortality and malformations)
- Total yield from 11 controlled production cycles
    - 694,000 fingerlings (1426 kg)
    - i.e. average weight 2.05 g, 78.9 % survival
- At least 4 cycles annually including sanitization
- Parallel use of the systems possible

→ at least 5 cycles per year

Parameter	n	mean	STD	Min	Max
Biomass (kg)	54	104.9	63.0	39.7	202.3
Water temperature (°C)	681	11.0	1.3	9.1	13.9
pH	54	7.3	0.2	7.1	7.7
Total ammonia (mg l^{-1})	54	0.9	0.6	0.2	2.3
Nitrite (mg l^{-1})	54	0.8	0.7	0.1	4.9
Nitrate (mg l^{-1})	54	47.6	33.4	11.0	96.3
Biological oxygen demand (mg l^{-1})	54	1.4	0.5	1.0	2.5
Chemical oxygen demand (mg l^{-1})	54	2.6	1.1	1.0	4.1
Suspended solids (mg l^{-1})	54	3.3	1.5	2.0	5.0
Chlorides (mg l^{-1})	54	94.1	37.58	43.71	130.96

How it worked?

Period	Duration		Losses	n
	days	%	%	
Hatching period	16.4 ± 2.2[b]	20.6 ± 2.8[b]	7.8 ± 3.8[b]	11
Initial feeding period	29.3 ± 4.3[a]	36.8 ± 5.4[a]	10.7 ± 3.5[a]	11
Rearing period	33.9 ± 3.2[a]	42.6 ± 4.0[a]	2.6 ± 0.8[c]	11
Production cycle	79.6 ± 4.7	100	21.1 ± 2.8	11

	FCR	
Period	period	average
Initial feeding period	0.55 ± 0.05[b]	0.66 ± 0.09
Rearing period	0.71 ± 0.07[a]	

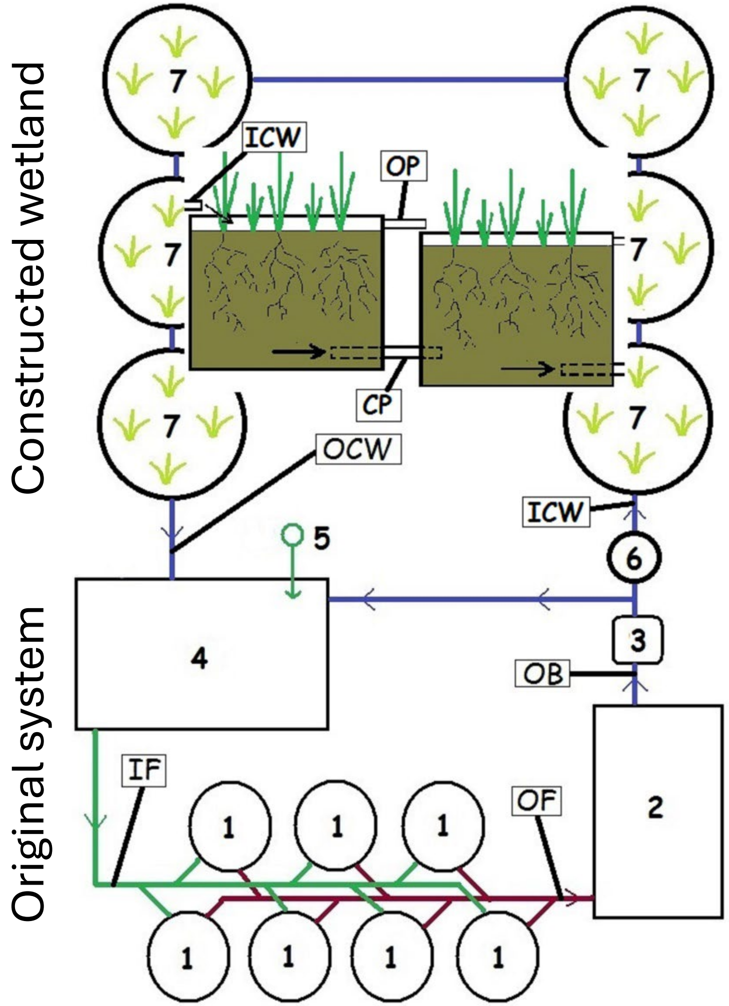
Is it worth it?

A lot!

Why not do more?

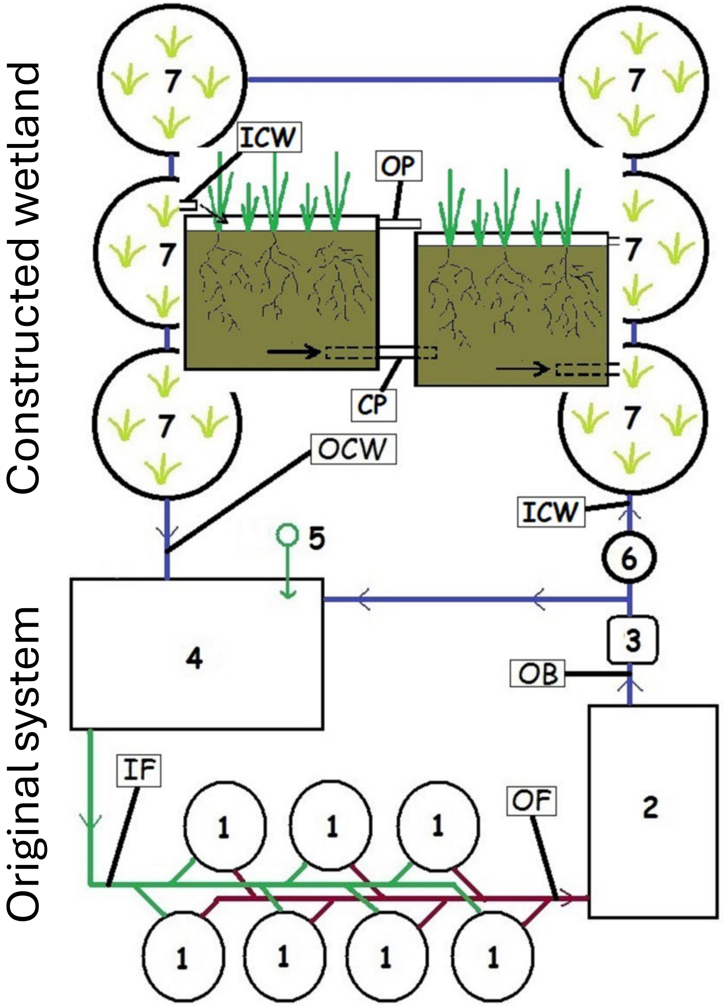
Incorporation of constructed wetland (CW)

- Added to existing „rearing system“ of RAS hatchery
- Evaluated economic feasibility and environmental impact
- Six tanks with 1.4 m^3 of inert substrate (clay pebbles) planted with reed canary grass and common reed (ca. 2:1)
- The tanks of CW arranged horizontally with a cascading flow
- Ball valve at the inlet to the CW enabled operation of the system with or without CW - no need for additional pumps / supplemental power
- 1/3 of the total water flow (~ 6 L s^{-1}) directed through CW = the total volume of the system passed through the CW > 2x per hour



Incorporation of constructed wetland

- Costs of adjustment (construction of CW) ca. **5300 €**
  - Concrete base
  - Concrete circular tanks with rubber sealing
  - Piping
  - Clay pebbles
  - Ball valve
  - Work
  - Wild plants – no costs
- Similar management of stocks
- Similar sampling of water and measurements
- Similar analysis



How it worked?

- 4 production cycles monitored with and 4 without CW
- Oxygen saturation 87–100% (inlet) and 79–97% (outlet)
- T = 9.2 - 12.4°C, pH values ~ 7
- Suspended solids concentration higher, but no impact on fish
- Mean - lower ammonia, no differences nitrate and nitrite
- Max. values – lower nitrous compounds in the terminal phase of rearing (biomass of ~230 kg and ~200 kg with and without CW)
- Reduced BOD = CW implied a potential final maximum **biomass of 40% over that obtained without the CW**

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How it worked? Chemistry...

Parameter	O	OM	n	Mean	STD	Min	Max
Biological oxygen demand (mg L^{-1})	CW	IF	21	*1.0[a]	0.0	*1.0	*1.0
		OF	21	*1.0[a]	0.0	*1.0	*1.0
		OB	21	*1.0[a]	0.0	*1.0	*1.0
		OCW	21	*1.0[a]	0.0	*1.0	*1.0
	X	IF	22	1.3[b]	0.5	*1.0	2.0
		OF	22	1.4[b]	0.6	*1.0	2.5
		OB	22	1.3[b]	0.5	*1.0	2.0
Chemical oxygen demand (mg L^{-1})	CW	IF	21	1.9[a]	0.4	1.4	2.5
		OF	21	2.1[a]	0.3	1.5	2.6
		OB	21	2.0[a]	0.3	1.5	2.5
		OCW	21	2.0[a]	0.4	1.1	2.4
	X	IF	22	2.5[a]	1.0	1.1	4.0
		OF	22	2.6[a]	1.1	1.0	4.1
		OB	22	2.6[a]	1.0	1.1	4.0

* The values of biological oxygen demand were below laboratory detection limits (1 mg L^{-1}).

Parameter	O	OM	n	Mean	STD	Min	Max
Total ammonia (mg L^{-1})	CW	IF	21	0.5[a]	0.2	0.2	0.7
		OF	21	0.6[a]	0.2	0.3	0.9
		OB	21	0.5[a]	0.2	0.2	0.8
		OCW	21	0.3[a]	0.3	0.1	0.8
	X	IF	22	1.0[b]	0.7	0.1	2.2
		OF	22	1.1[b]	0.7	0.2	2.3
		OB	22	1.0[b]	0.7	0.1	2.3
Nitrite (mg L^{-1})	CW	IF	21	0.3[a]	0.2	0.1	0.8
		OF	21	0.3[a]	0.3	0.1	1.1
		OB	21	0.4[a]	0.2	0.1	0.9
		OCW	21	0.3[a]	0.3	0.1	1.0
	X	IF	22	1.0[a]	1.5	0.1	4.9
		OF	22	0.9[a]	1.3	0.1	4.3
		OB	22	1.0[a]	1.3	0.1	4.5
Nitrate (mg L^{-1})	CW	IF	21	25.2[a]	12.6	7.3	41.9
		OF	21	24.6[a]	14.3	7.9	49.8
		OB	21	25.5[a]	14.1	7.6	51.7
		OCW	21	26.0[a]	13.9	6.9	53.1
	X	IF	22	21.5[a]	24.5	5.0	73.8
		OF	22	21.1[a]	24.3	5.0	72.9
		OB	22	21.6[a]	24.8	5.0	74.0

How it worked?

- Length of production cycle, mortality, FCR - similar
- The mean biomass was higher in trials with CW
- Final biomass even 40% greater than without CW
- Fresh water demand slightly increased - 0.3 m^3 day^{-1}
- No energy demand difference
- Labour comparable, but additional ~8 h per year for cutting of plants and composting the biomass
- The calculation of potential annual production made with and without CW for two levels of initial stocked biomass

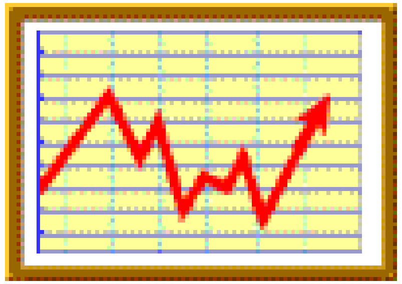
Operational system	With CW		Without CW	
Parameter	Mean biomass	Max. biomass	Mean biomass	Max. biomass
Biomass (kg)	131.7	239.4	102.6	199.7
Ammonia (mg L^{-1})	0.5	0.7	1.0	2.2
Nitrite (mg L^{-1})	0.3	0.8	1.0	4.9
Water demand (L s^{-1})	0.06		0.05	
Capacity (kg)	~ 280 - 290		~ 200	

How it worked? Comparison of costs

With CW	days per PC	Energy consumption per day (kWh)	Energy consumption total per PC (kWh)	Freshwater demand per day (m^3)	Freshwater demand total per PC (m^3)	Labour per day (hr)	Labour total per PC (hr)
Phase 1	44.8	20.9	936.3	0.86	38.53	< 4	< 179.2
Phase 2	32.8	25.7	843.0	4.32	141.70	< 3	< 98.4
PC	77.5	23.0	1779.3	2.33	180.22	< 3.58	< 278.0

Without CW	days per PC	Energy consumption per day (kWh)	Energy consumption total per PC (kWh)	Freshwater demand per day (m^3)	Freshwater demand total per PC (m^3)	Labour per day (hr)	Labour total per PC (hr)
Phase 1	44.1	20.9	921.7	0.86	37.93	< 4	< 176.4
Phase 2	35	25.7	899.5	3.46	121.10	< 3	< 105.0
PC	80	23.1	1 821.2	2.01	159.03	< 3.56	< 281.4

How it worked? Economical point of view



Operation	With CW		Without CW	
Initial stock (pcs)	90,000	110,000	90,000	110,000
Total losses (%)	25	25	25	25
Number of fingerlings per PC	67,500	82,500	67,500	82,500
Final biomass (kg)	max 280	max 280	max 200	max 200
Mean weight (g)	4.15	3.39	2.96	2.42
Price of fingerlings per PC (€)*	15,508	17,595	13,809	15,858
Price of fingerlings per year (€)*	62,032	70,380	55,236	63,432

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Conclusions

- Eight production cycles showed the potential of CW integration
- **Expanded production without increased operation costs or environmental load**
- It allows the rearing about **40% higher fish biomass → higher production → profitability**
- Can enhance profitability of existing hatcheries all scale facilities
- Has potential to be **sustainable in the context of climate change and resource limitations**
- (Vermi)Composting of green material possible
- Supply for own farms or / and for sale
  - *Rainbow trout*
  - *Brook trout (char)*
  - *Brown trout*
  - *Atlantic salmon*
  - *Tomatoes, cucumbers.....*

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Thank you for you attention

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