University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Daithi O'Murchu Marine Research Station

From seaweed to samphire – what works for maraponics?

Gavin Burnell
Daryl Gunning

IRISH RESEARCH COUNCIL
An Chomhairle um Thaighde in Éirinn

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Introduction

- What is **maraponics**?

  = **marine aquaponics** = RAS + IMTA (integrated multi-trophic aquaculture)

Background

- ➢ Difficult to obtain licenses for mixed species culture in Ireland
- ➢ Hard to demonstrate nutrient recycling in oligo/mesotrophic open water IMTA

- ➢ RAS allows full control of inputs
- ➢ RAS allows behavioural observations
- ➢ Experiment with different species mix
- ➢ Reduced sampling variability (diurnal/tidal)

Aims

- Measure the growth and survival of chosen macroalgae and invertebrates (Exp 1 & 2)

- Map the production and recycling of fatty acids through three trophic levels (Exp 1)

- Measure the performance of Sea Samphire on aquaculture waste water using aeroponics (Exp 3 & 4)

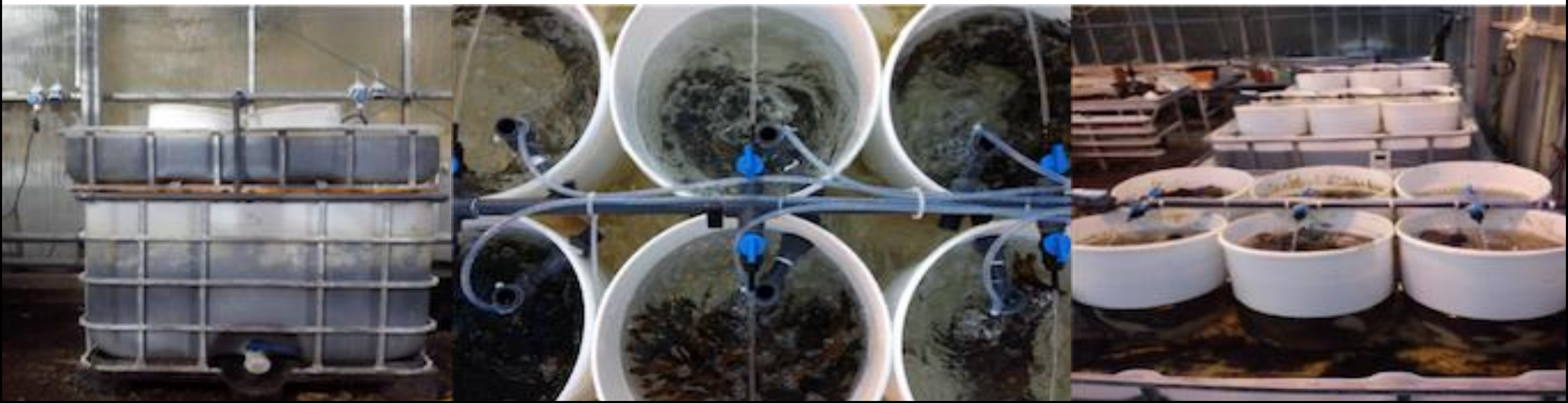
Exp 1 Integrated Bulk Carrier (IBC) - winter

- Assess growth rates of:
  - Seaweed (*Laminaria digitata; Ulva lactuca, Ascophyllum nodosum; Fucus serratus; F. vesiculosus; Pelvetia canaliculata*)
  - Blue mussel (*Mytilus edulis*); Cotton spinner sea cucumber (*Holothuria forskali*); & Japanese abalone (*Haliotis discus hannai*)

- Addition of salmon faeces, feed, and ammonia based on Winfish model (Ferreira *et al*. 2012)

- Monitor water quality parameters

- Conduct fatty acid analysis on maraponic components (salmon faeces and feed; seaweeds; flesh of mussels, sea cucumbers, & abalone)



Exp 1 – Preliminary results

- Water quality parameters across each unit demonstrated little variation:
  - salinity: 31.7-32ppt
  - pH: 8-8.2
  - DO: 9.5-10.2mg/L
  - temperature: 13.8-14.8°C
  - mean ammonia levels showed slight variation between each system

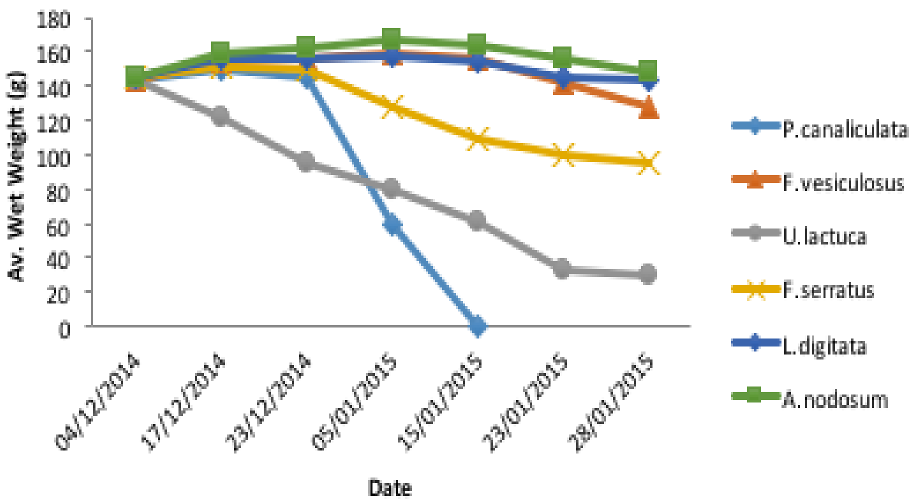
    IBC 1: 0.778 mg/L

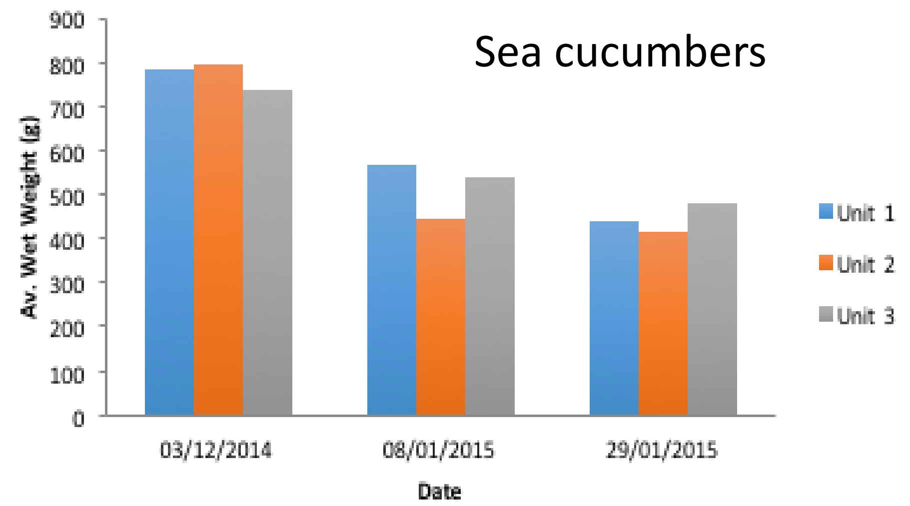
    IBC 2: 0.578 mg/L

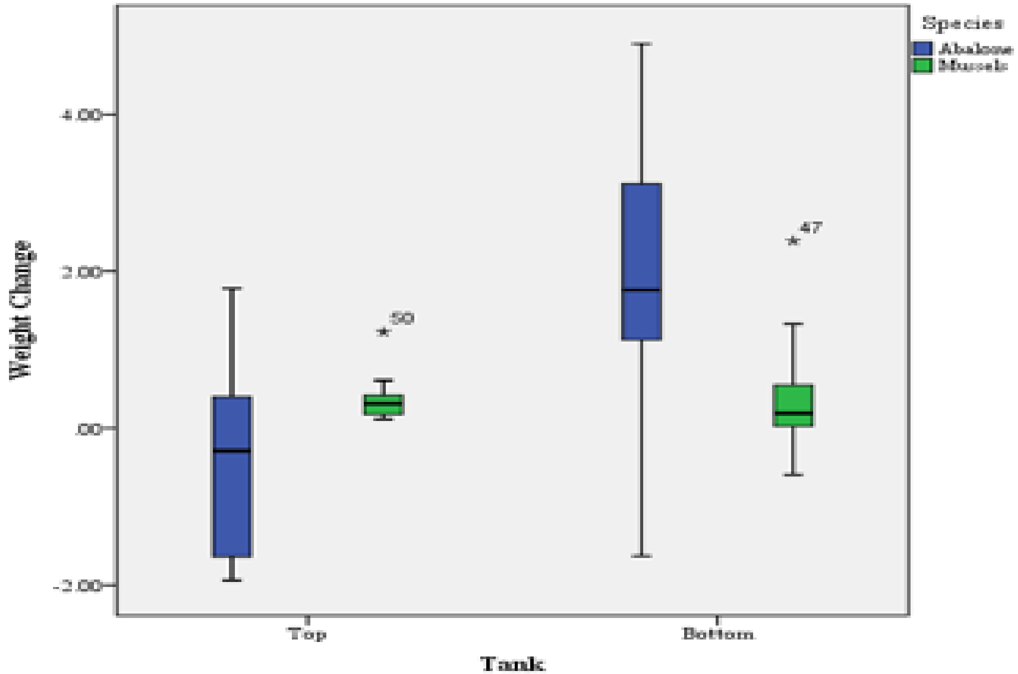
    IBC 3: 0.60 mg/L

  - Stored water samples awaiting nitrite, nitrate etc. analysis

Exp 1 – preliminary growth results







Exp 1 Fatty Acid (FA) analysis

AIMS

- to determine **FA** composition of species growing in maraponic unit

- to map **FA**s through the trophic levels

FA analysis - mussels

salmon feed/faeces markers such as 18:1n-9; 20:1n-9; 22:1n-11; and arachidonic acid (ARA) detected in mussels

W.H.O. currently recommend that ratio of ω6:ω3 in the diet should be < 10

control mussels: ω6:ω3 = 0.2 ± 0.0

maraponic mussels: ω6:ω3 = 0.2 ± 0.1 (top tank)

0.3 ± 0.1 (lower tank)

FA analysis - abalone

salmon feed/faeces markers such as 20:1n-9; 22:1n-11; 18:2n-6 and DHA detected in abalone tissue

control abalone: docosahexanoic acid (DHA) = (0.0±0.1)

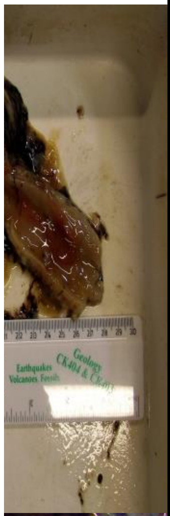
maraponics abalone: DHA = 0.8±0.4 (top tank)
DHA = 3.9±1.2 (lower tank)

Ratio of ω6:ω3

control abalone: ω6:ω3 = 0.4 ± 0.0
maraponic abalone: ω6:ω3 = 0.4 ± 0.0 (top tank)
= 0.3 ± 0.0 (lower tank)

	PRETRIAL	TRIAL BOTTOM	*P*-Value
LIPID %	1.4 ± 0.4	1.9 ± 0.7	NS
FATTY ACIDS			
14:0	1.5 ± 0.7	0.9 ± 0.9	NS
16:0	3.6 ± 1.2	3.0 ± 2.1	NS
18:0	4.1 ± 0.9	4.7 ± 1.3	NS
19:0	1.4 ± 0.4	1.5 ± 0.2	NS
20:0	1.8 ± 0.1	2.1 ± 0.2	NS
21:0	1.6 ± 0.3	1.6 ± 0.4	NS
22:0	1.9 ± 0.4	2.0 ± 0.4	NS
Total SFA[1]	*19.7 ± 0.9*	*19.6 ± 4.3*	*NS*
16:1n-7	3.3 ± 0.6	2.6 ± 2.1	NS
18:1n-9	3.4 ± 2.3	3.1 ± 1.5	NS
18:1n-7	4.4 ± 0.3	4.2 ± 1.1	NS
20:1n-11	4.5 ± 0.3	4.7 ± 1.1	NS
20:1n-9	1.8 ± 0.8	1.8 ± 1.1	NS
20:1n-7	0.8 ± 0.2	1.0 ± 0.3	NS
22:1n-11	0.9 ± 0.2	1.0 ± 0.4	NS
22:1n-9	1.2 ± 0.4	1.4 ± 0.3	NS
23:1n	7.7 ± 3.3	5.9 ± 1.8	NS
24:1n-9	1.6 ± 0.2	1.8 ± 0.4	NS
Total MUFA[2]			*NS*
18:2n-6	0.3 ± 0.2	0.3 ± 0.1	NS
20:2n-6	1.5 ± 0.1	1.6 ± 0.2	NS
ARA	14.0 ± 1.7	12.9 ± 4.0	NS
22:5n-6	1.2 ± 0.4	1.5 ± 0.3	NS
Total n-6 PUFA[3]	*18.0 ± 2.3*	*17.0 ± 4.2*	*NS*
18:3n-3	0.7 ± 0.2	0.7 ± 0.5	NS
18:4n-3	1.4 ± 0.8	1.0 ± 0.8	NS
EPA	16.1 ± 3.5	16.8 ± 4.9	NS
22:5n-3	0.6 ± 0.2	0.5 ± 0.4	NS
DHA	2.3 ± 0.3	2.4 ± 0.7	NS
Total n-3 PUFA[4]	*22.0 ± 4.4*	*23.4 ± 4.8*	*NS*
Total PUFA[5]	*40.5 ± 6.4*	*41.3 ± 6.4*	*NS*
18:0 DMA	5.9 ± 1.0	6.1 ± 1.5	NS
19:0 DMA	1.8 ± 0.4	1.7 ± 0.7	NS
Total DMA	*7.7 ± 1.4*	*7.9 ± 2.0*	*NS*
W6/W3	*0.8 ± 0.1*	*0.8 ± 0.2*	*NS*

	PRETRIAL	TRIAL BOTTOM	*P*-Value
LIPID %	0.3 ± 0.1	0.3 ± 0.1	NS
FATTY ACIDS			
14:0	0.5 ± 0.4	0.7 ± 0.4	NS
16:0	3.2 ± 1.4	3.9 ± 3.4	NS
18:0	3.1 ± 0.4	3.5 ± 0.6	NS
19:0	1.4 ± 0.2	1.3 ± 0.1	NS
20:0	2.4 ± 0.1	2.3 ± 0.3	NS
21:0	2.1 ± 0.3	2.1 ± 0.4	NS
22:0	2.3 ± 0.1	2.5 ± 0.2	NS
Total SFA[1]	*17.3 ± 2.8*	*18.8 ± 8.1*	*NS*
16:1n-7	1.1 ± 0.8	1.1 ± 0.4	NS
18:1n-9	3.3 ± 0.5	3.8 ± 1.3	NS
18:1n-7	2.2 ± 0.4	2.0 ± 0.3	NS
20:1n-11	8.2 ± 1.1	7.3 ± 1.6	NS
20:1n-9	0.6 ± 0.8	0.9 ± 0.5	NS
20:1n-7	0.5 ± 0	0.4 ± 0.1	NS
22:1n-11	0.7 ± 0	0.6 ± 0.1	NS
22:1n-9	1.9 ± 0	1.8 ± 0.2	NS
23:1n	9.4 ± 0.5	10.1 ± 0.7	NS
24:1n-9	2.9 ± 0.5	3.3 ± 0.8	NS
Total MUFA[2]	*31.9 ± 1.3*	*32.8 ± 1.8*	*NS*
18:2n-6	0.2 ± 0	0.2 ± 0.2	NS
20:2n-6	1.6 ± 0.2	1.3 ± 0.2	NS
ARA	20.4 ± 2.5	16.6 ± 5.5	NS
22:5n-6	1.5 ± 0	1.3 ± 0.4	NS
Total n-6 PUFA[3]	*24.4 ± 2.6*	*20.2 ± 6.3*	*NS*
18:3n-3	0.2 ± 0.2	0.3 ± 0.2	NS
18:4n-3	0.3 ± 0.1	0.4 ± 0.2	NS
EPA	12.1 ± 1.3	10.2 ± 4.1	NS
22:5n-3	0.3 ± 0	0.2 ± 0.1	NS
DHA	1.1 ± 0.3	0.8 ± 0.4	NS
Total n-3 PUFA[4]	*14.8 ± 0.8*	*12.9 ± 4.8*	*NS*
Total PUFA[5]	*40.0 ± 3.2*	*33.9 ± 10.0*	*NS*
18:0 DMA	8.0 ± 0.8	8.7 ± 0.5	NS
19:0 DMA	2.5 ± 0	2.4 ± 0.4	NS
Total DMA	*10.5 ± 0.7*	*11.2 ± 0.8*	*NS*
W6/W3	*1.7 ± 0.1*	*1.6 ± 0.4*	*NS*



FA analysis overall findings

- Lipid composition of salmon feed 5 times higher than salmon faeces
- Identified biomarkers:
  - 18:1n-9; 20:1n-9; 22:1n-11; 18:2n-6; ARA; & DHA
- Evidence that mussels and abalone feeding upon salmon feed and faeces
- Sea cucumbers – greater variability between individuals
- Seaweed FA analysis awaiting completion

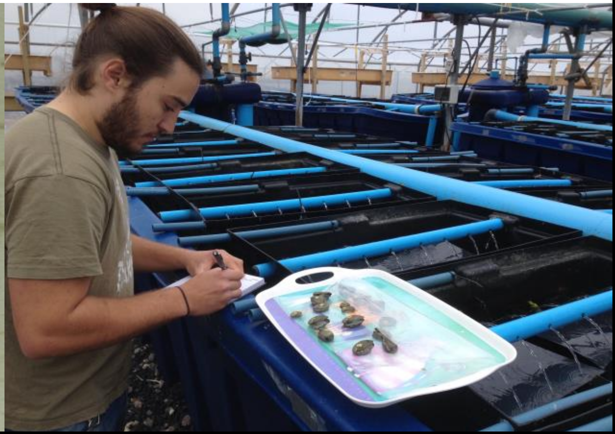
Exp 2 IBC - summer

- Assess growth of:
  - Macroalgae: *Himanthalia elongata; Ulva lactuca; Fucus vesiculosus.; F. serratus; Laminaria digitata; Ascophylum nodosum*
  - Purple sea-urchin: *Paracentrotus lividus*
  - Abalone: *Haliotis tuberculata* and *H. discus hannai*
  - Blue mussel: *Mytilus edulis*

- Salmon waste and ammonia (no salmon feed)

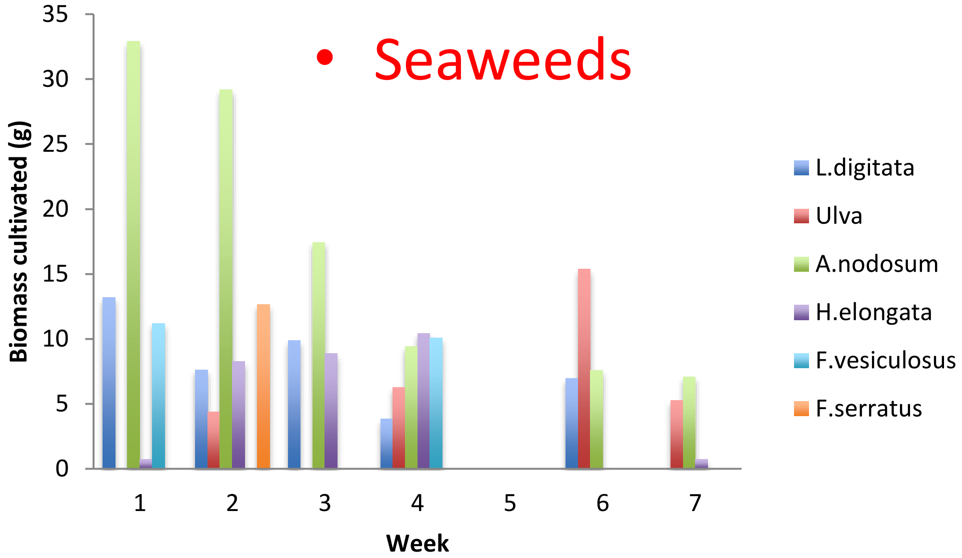
- Excess seaweed biomass fed to abalone in top tray

- Nitrites and Nitrates also monitored 2-3 times per week



Exp 2 – Preliminary results

- Seaweeds



- Sea urchins:
  - 100% retention of tags & no mortalities*
  - Very small level of growth (NS)
  - Mortalities only seen at end of trial

- Mussels and abalone
  - Small level of growth seen in mussels (weight {av. + 0.3g} & width {av. +0.19})
  - *H.tuberculata*: Length (av. + 2.64mm); Width (av. + 2.64mm); Weight (av. +1.56g)
  - *H.discus hannai*: Length (av. + 1.47mm); Width (av. + 1.13mm); Weight (av. +0.77g)

Baseline IBC Parameters	Average
Ambient Temperature	21.7°C ± 2.7
Water Temperature	19.5°C ± 2.2
pH	7.936 ± 0.319
Salinity	35.4 ± 0.6
Dissolved Oxygen	8.53mg/L ± 5.63
Dissolved oxygen saturation	89% ± 16
Ammonia	1.11mg/L ± 0.85
Nitrite	0.132mg/L ± 0.116
Nitrate	1.351 mg/L ± 0.761

Summary of Exp 1&2 results

sea cucumbers are NOT super heroes

mussels and abalone can intake salmon feed/faeces

Various studies have determined the diet of abalone is mainly macroalgae based (Bansemer et al. 2014; Garcia-Carreno et al. 2003; & Mai et al. 1996)

seaweeds need more light in winter

Growth of sea samphire (Salicornia europaea) in aeroponics systems

- Exp 3 (Growth media)

  Treatments:

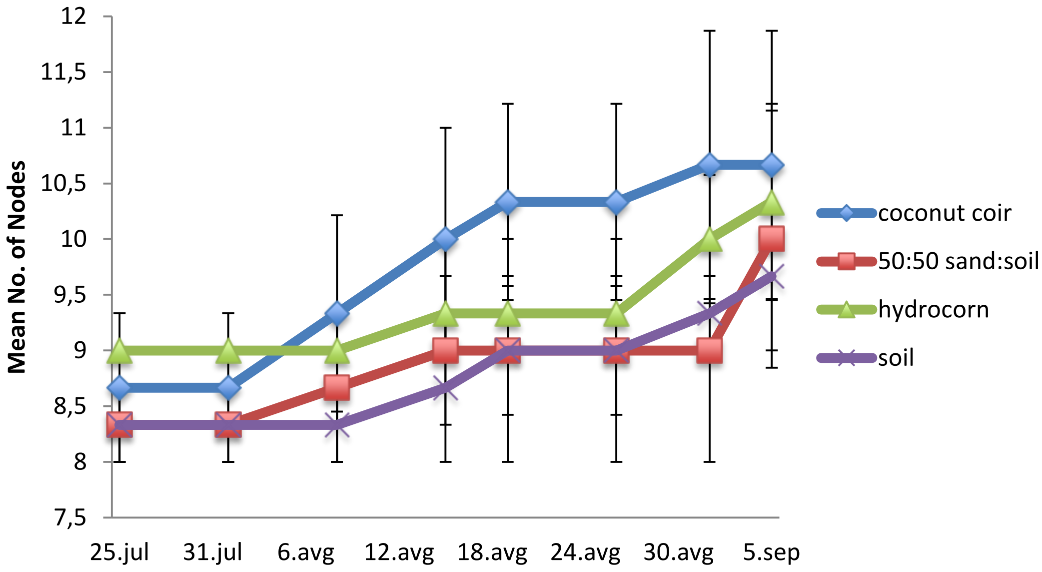
  sand:soil (50:50)
  soil
  hydrocorn
  coconut coir

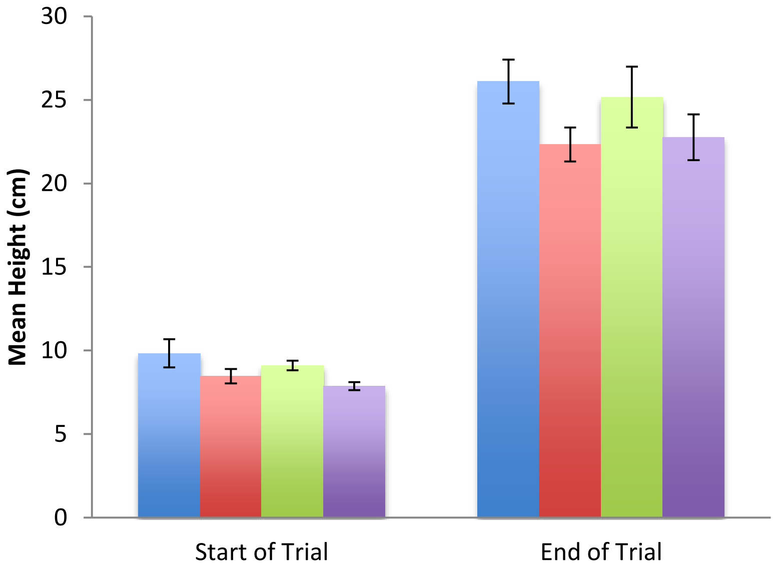
- Exp 4 (Oyster hatchery wastewater trial)

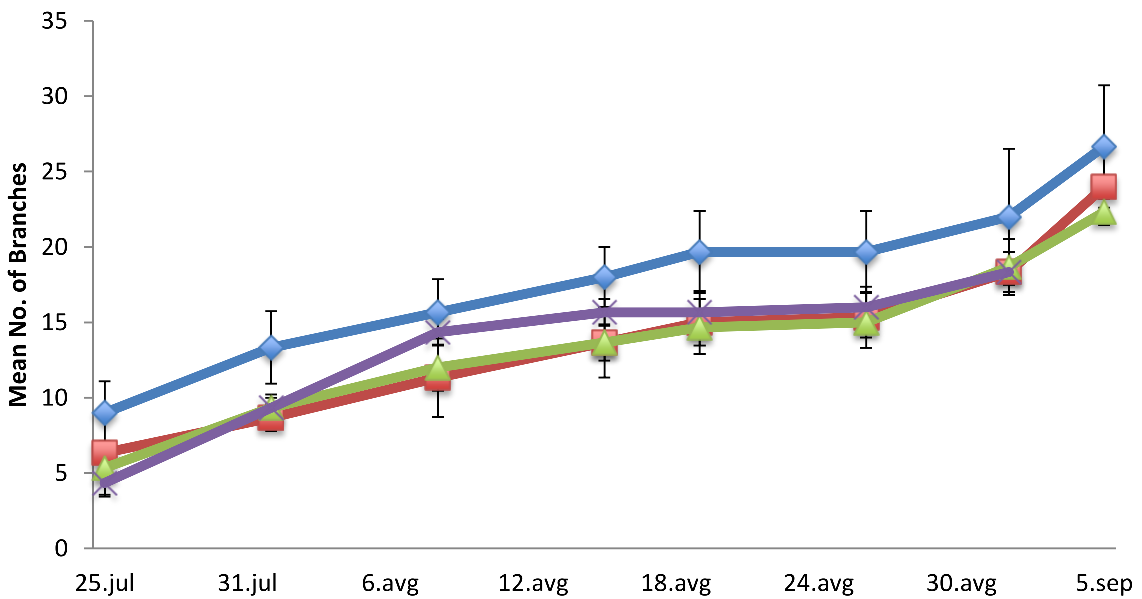
  Treatments:

  1. saline waste water:freshwater (1:2)
  2. saline waste water:freshwater (2:1)
  3. saline waste water (100%)

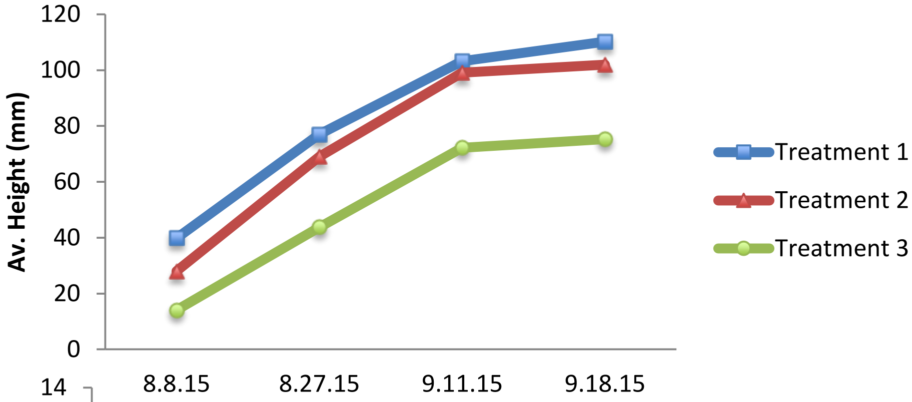
Exp 3 results – growth media

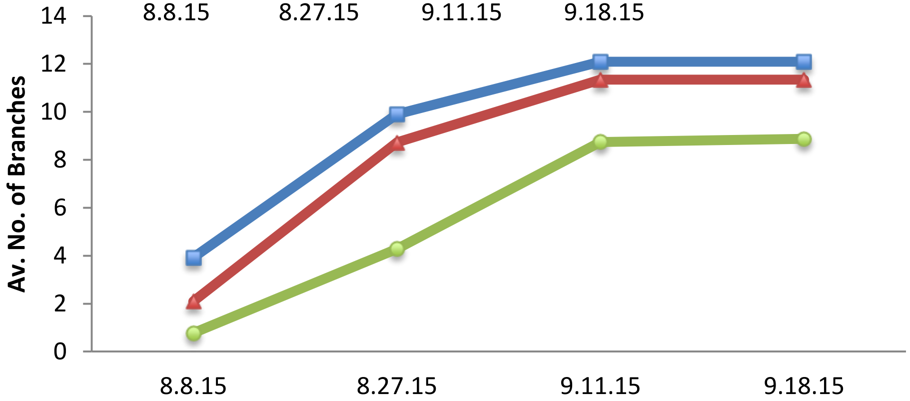


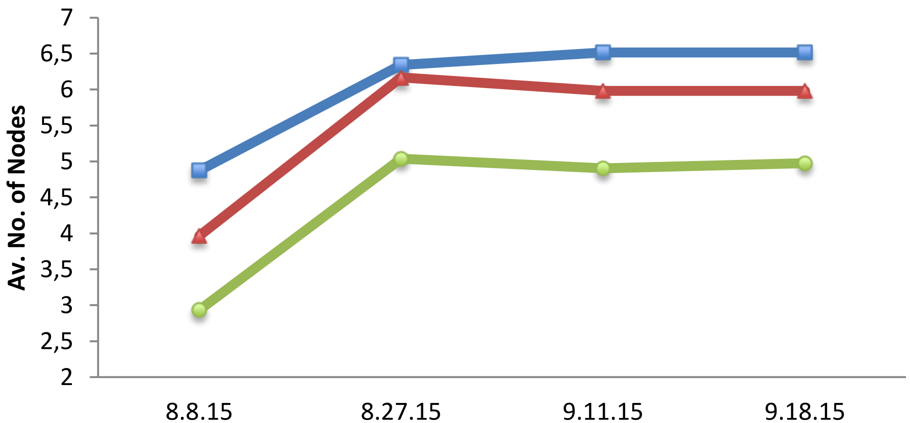


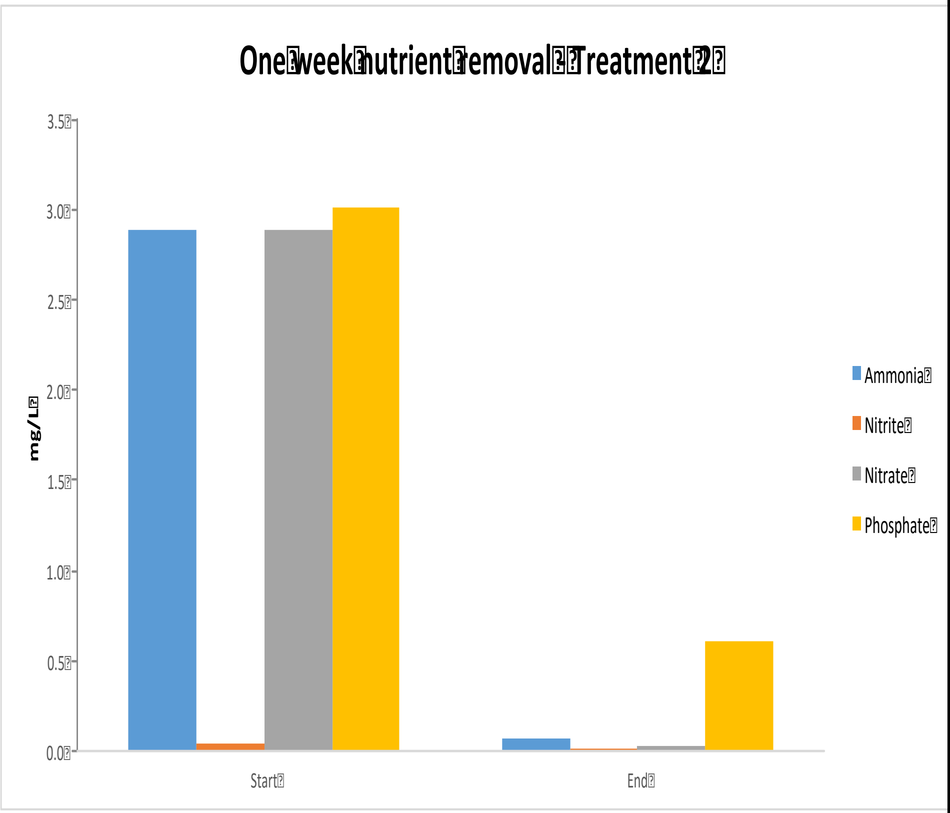


Exp 4 results – hatchery wastewater









Summary of Exp 3 & 4 results

- coir was the best growth media
- most dilute (brackish) waste water gave best growth
- *Salicornia* removes high percentage of waste nutrients

References

- Bansemer *et al*. (2014). Nutritional requirements and use of macroalgae as ingredients in abalone feed. *Reviews in Aquaculture*, 5, pp. 1-15.

- Ferreira *et al*. (2012). Cultivation of gilthead bream in monoculture and integrated multi-trophic aquaculture. Analysis of production and environmental effects by means of the FARM model. *Aquaculture*, 358-359, pp. 23-34.

- Garcia-Carreno *et al*. (2003). Digestive enzymes in juvenile green abalone, Haliotisfulgens, fed natural food. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology*, 134(1), pp. 143-150.

- Handå *et al*. (2012). Incorporation of salmon fish feed and feces components in mussels (*Mytilus edulis*): Implications for integrated multi-trophic aquaculture in cool-temperate North Atlantic waters. *Aquaculture*, 370-371, pp. 40-53.

- Irisarri *et al*. (2015). Availability and utilization of waste fish feed by mussels, *Mytilus edulis*, in a commercial integrated multi-trophic aquaculture (IMTA) system: A multi-indicator assessment approach. *Ecological Indicators,* 48, pp. 673-686.

- Mai *et al*. (1996). Comparative studies on the nutrition of two species of abalone, *Haliotis tuberculata* L. and *Haliotis discus hannai* Ino. V. The role of polyunsaturated fatty acids of macroalgae in abalone nutrition. *Aquaculture,* 139(1), pp. 77-89.

- Nelson *et al*. (2002). Comparison of growth and lipid composition in the green abalone, *Haliotis fulgens*, provided specific macroalgae diets. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology,* 131(4), pp. 695-712.

- Stabili *et al*. (2012). The lipidic extract of the seaweed *Gracilariopsis longissima* (Rhodophyta Gracilariales): a potential resource for biotechnological purposes? *New Biotechnology*, 29(3), pp. 443-450.