INTEGRATE FACTSHEET 2

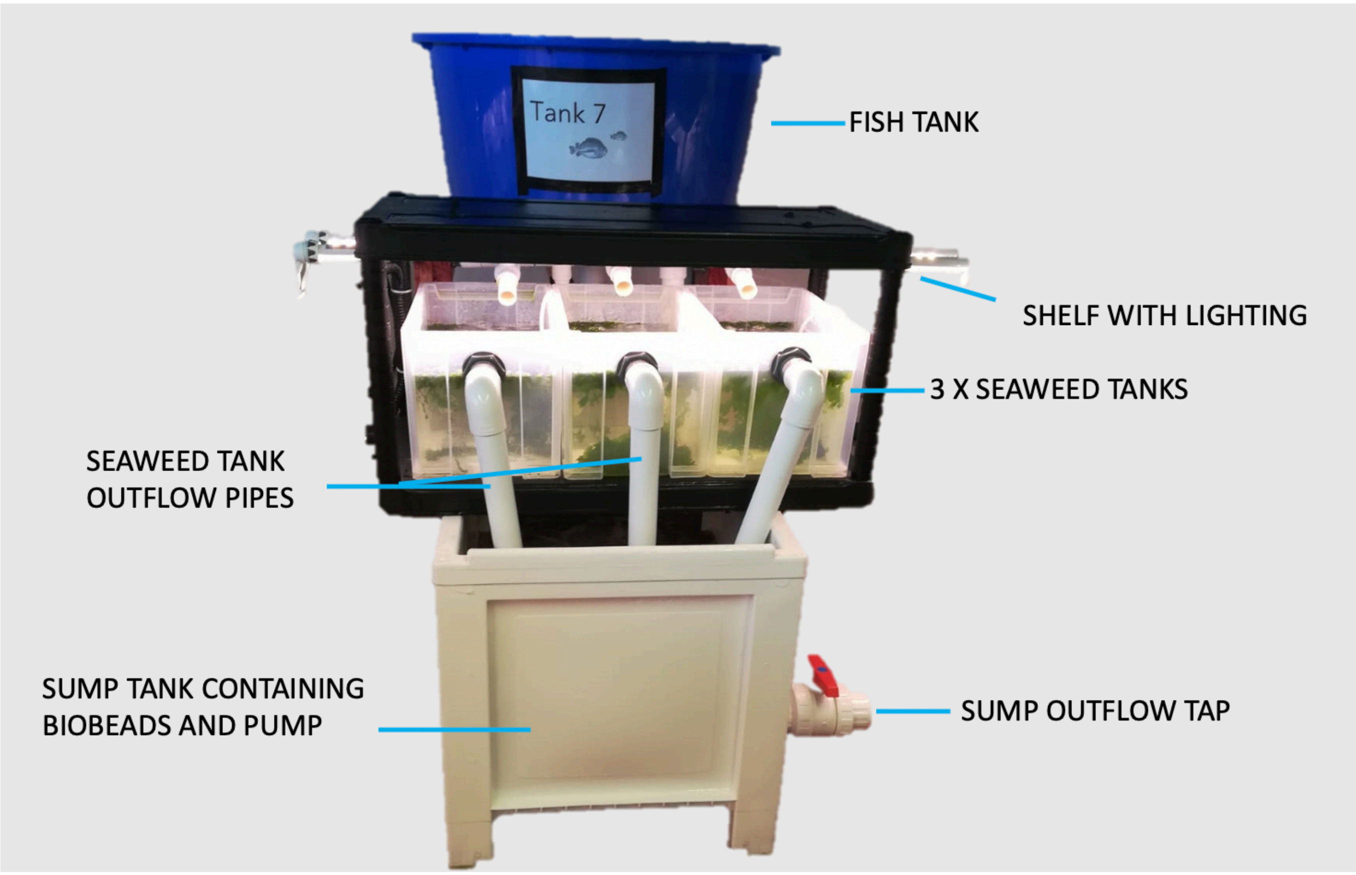
Establishing a recirculating IMTA system

Irish Seaweed Research Group & Aquaculture Nutrition and Aquafeed Research Unit
The Ryan Institute, National University of Ireland, Galway

INTRODUCTION

This factsheet will provide a brief overview of what is needed in order to construct a simple, 2-trophic level **recirculating aquaculture system (RAS)**, some factors that need to be taken into account when making design decisions, and the specification of the component parts that will be used. This is not a step-by-step guide, but rather an overview of some things that are important to consider before designing a system and/or buying component parts. It should be read in conjunction with Factsheet 3 (Managing a pilot-scale recirculating IMTA system) as some of the factors mentioned there are also important to consider prior to designing a system. A selected bibliography is included at the end for those who want greater detail of some of the topics mentioned.

Based on: **Our model – A fish (lumpsucker; *Cyclopterus lumpus*) and seaweed (sea lettuce; *Ulva* spp.) marine partial RAS** (below).



WHAT YOU WILL NEED

COMPONENTS:

- Fish tank(s)
- Seaweed tank(s)
- Sump tank with biofilter
- Pipework and taps for flow modulation
- Pump
- Air/oxygen
- Filters for organic matter
- Lights/shade screens
- Escape prevention features

Suggested **SUPPLIERS** for Ireland, the UK and Europe:

- Aquacultur Fischtechnik GMBH
- Tropical Marine Supplies
- Maidenhead Aquatic
- Irish Box Company

ASSEMBLY:

When you have designed your prototype (see below) you will need to assemble it *without* gluing or sealing it permanently, to see if and how it works. It is likely that some adjustments will need to be made. Silicone sealant, or jubilee clips will work as a temporary holds where pipes are not close-fitting enough to withstand the pressure of testing the system. Experience is very helpful when designing and building, but failing this trial, error and patience will work.

FAILURE POINTS:

- Matching pump capacity to required flow.
- Under-sizing the pipes resulting in particulate and bacterial build-up and potential reduced flow or blockages.

★ KEY POINTS

- Ensure your equipment and fittings are **MARINE GRADE**
- When ordering pipes, make sure that you know if you are measuring & ordering the internal or external diameter
- **Safety and IP ratings:** All electrical fixtures must be waterproof and appropriately rated to the correct IP (ingress protection) specification. These ratings specify degree of protection from foreign bodies (i.e. dust) and moisture. **IP67** rated sockets/plugs, light fittings etc. will give full protection from dust and other particulates and against full immersion for up to 30 minutes between 15cm and 1m depth. These ratings are defined by international standards.

THINGS TO CONSIDER

WATER FLOW – PUMP

Why it's necessary: Flowing water acts to mitigate metabolic waste products building up in the habitat tanks and also aids in the distribution of necessary resources (e.g. feed/nutrients/oxygen). The overall flow rate will be likely to be (not necessarily) dictated by the needs of the fed species and the pump must be sufficient to deliver this flow rate.
Things to think about: When estimating pumping rate, it is important to consider the height over which the pump is expected to function (i.e. if the water must be lifted). This is termed **'head height'** and should be taken into consideration in the flow calculations. Pump specifications will detail both maximum flow rates and adjusted flow rates at height. For small scale experimental systems aquarium or pond pumps are sufficient. Our system used a pump to circulate water from the **sump** (lowest point) up to the fish tank (highest point), and following that the flow was gravity fed to maximise the efficiency of the system.

★ **Key Points:**

- Look for pumps with **ceramic impellers** – important for avoiding corrosion and ensuring pump longevity
- Check the **cable length** that is supplied; look for options to specify the cable length to suit your system

Our model: Laguna MaxFlo 2200 (max. head height 1.8m, max. flow rate 2200 lph, flow rate at 1m 1330 lph)

PARTICULATE FILTRATION (SOLIDS/ORGANIC WASTE REMOVAL)

Why it's necessary: Particulate matter is generated by breakdown of feed and by production of faeces, and depending on the source of water used to fill/refresh the system this can also contribute. It is important to remove particulate matter quickly from the system for several reasons: it is a surface on which bacteria can grow; as organic matter degrades it releases nitrogen and phosphorus compounds into the water reducing water quality and impacting fish health; as particle flocs break down they produce very fine suspended solids which are difficult to remove (and are again a surface upon which bacteria can grow); solids can block pumps and pipework eventually resulting in system failure.

Mechanical: Several types of mechanical filtration are commonly used in recirculating systems, each having their own advantages and disadvantages, e.g.; drum filters, sock filters, swirl separators, pressurised sand filters, canister filters. The simplest type of filtration is the sock filter, a nylon or polypropylene fibre bag through which the water passes as it circulates through the system. Different mesh sizes (e.g. 200 – 50 µm) can be chosen in accordance with the likely size of the particulate matter.

Our Model: Aquahabits 100 micron filter bag (sock filter)

IMTA option: Filter feeders and detritivores are employed in IMTA systems to remove some of the particulate load and are sometimes referred to as **organic extractive organisms**. It is necessary to understand and match the particle characteristics that are input to the system (i.e. waste feed and faeces) with those that will support the filter feeder. This is with regard to size, quantity and nutritional quality of the particles. Filter feeders - Bivalves e.g. mussels, oysters, scallops; gastropods e.g. abalone. Detritivores e.g. polychaetes, sea cucumbers and sponges.
Our system did not include a particulate removing extractive organism.

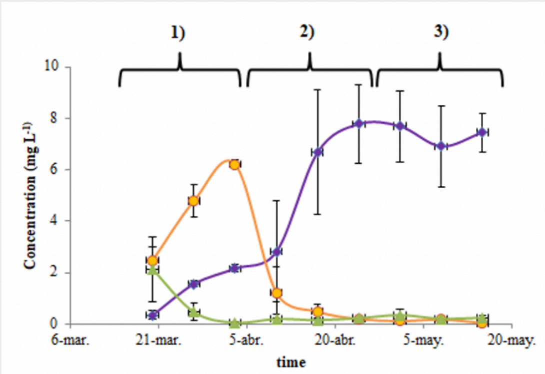
BIOLOGICAL FILTRATION (DISSOLVED/INORGANIC WASTE REMOVAL)

Why it's necessary: Biological filtration takes care of removing *dissolved metabolic waste* from the system; specifically, it uses the nitrification process to convert toxic metabolic products such as ammonia into less toxic nitrite and nitrate.

Traditional: Traditional bio-filtration uses a substrate with a very large surface area, typically biobeads that can be synthetic (plastic) or natural (e.g. ceramic, lava). These are usually housed in a sump tank that receives the water from the organism tanks, and allows a certain amount of nutrient processing before recirculating it into the system.

Biofilter establishment

This part of the process sits somewhere between setting up the system and managing it. The nitrifying bacteria that colonise the biobeads to provide biofiltration must have time to become established so that when animals are introduced to the system they are able to process waste immediately and the water quality does not deteriorate. The graph (right) shows the concentration of ammonia, nitrite and nitrate over time, during biofilter establishment as the bacterial populations establish and settle to those of a mature biofilter, finally showing a high concentration of nitrate and low concentrations of nitrite and ammonia. Further details are given in Factsheet 3.



Ammonia: Nitrite: Nitrate:

1: ammonia decreasing, nitrite increasing
2: nitrite decreasing, nitrate increasing
3: ammonia and nitrite stable and low, nitrate stable and high

IMTA option: The IMTA option uses **inorganic extractive organisms,** e.g. plants and/or algae, in full or partial replacement of the bacterial biofilter. These organisms utilise the dissolved nitrogen and phosphorus compounds thereby removing them from the circulating water. Different species have different affinities for nitrate and ammonia, and some can also utilise urea, so can be chosen according to the characteristics of the system.
Our system included several species of the genus *Ulva*, of both lamina and tubular morphologies, to investigate their potential as biofilters for lumpsucker waste. We used a biobead biofilter in addition to this, to ensure that the water quality remained sufficient for lumpsucker health while we worked to understand how the *Ulva* fitted into the system. One consequence of this was that the main form of nitrogen available to the seaweed was as nitrate; if the biobead biofilter was removed there would have been a higher concentration of ammonia available as well. *Ulva* spp. are able to utilise both nitrate and ammonia but one form of nitrogen may be better at promoting growth than another. These are questions that may be looked in each system that is designed and set-up, to work towards optimal functioning.

ADDITIONAL SYSTEM COMPONENTS

PROTEIN SKIMMERS: These remove fat-based waste and scum, thereby removing excess surface area on which growth of microorganisms can occur. We did not use protein skimmers in our system.

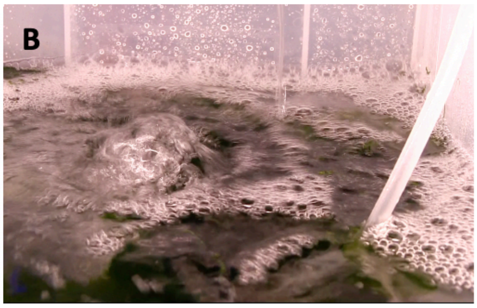
UV STERILISATION: As closed systems, recirculating systems can be prone to the build-up of circulating microorganisms; as mentioned above, many of the features of the system aim to minimise potential for these to grow. UV sterilisation is a final step in ensuring that the circulating water does not contain populations of bacteria that can very easily be stimulated into bloom conditions due to the nutrient rich environment. Blooms can result in decreased water quality (light, oxygen as they senesce), and/or the species of blooming bacteria may be pathogenic. **Our Model: TMC Vecton 600 – Picture A below**

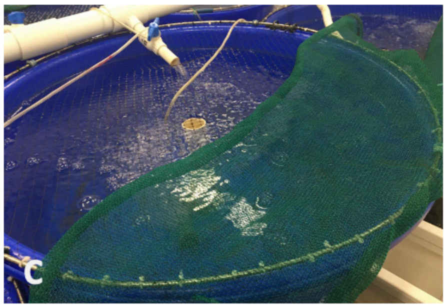
HABITAT MODIFIERS

It is likely that organisms in a system will have different environmental requirements requiring adjustments in their individual habitats. The following are some common examples:

Light: Many photosynthetic species will require enhanced light conditions in order to attain maximal productivity. At the simplest this may mean altering the number of hours of light – *photoperiod** – but quality, or spectral composition of light may also be important in regulating aspects of growth and reproduction or modifying chemical composition of algae. Fish generally require photoperiods of 8-16 or 12-12 hours of light:dark. **Shade & Escape Prevention:** Some fish species are more comfortable in shaded conditions where they can 'hide'. Picture C below shows a large-meshed net covering the tank to prevent accidental escapes, and a small-meshed green net providing shade and cover. Mesh covers are also useful over all outflow/stand pipes. **Tank colour:** Translucent/white tanks are generally not used; blue and green coloured tanks are often less stressful for fish. **Tank shape:** Circular/elliptical tanks may promote swimming and help avoid 'dead zones' where water becomes stagnant, but are less space efficient than square or rectangular tanks. Raceways with rounded ends can be a compromise that are the best of both. **Aeration:** Air may be provided to keep water in circulation and prevent stagnant areas from occurring. This is also useful for maintaining macroalgae in suspension, disrupting *boundary layers** and ensuring equal access to light and nutrients. A silicone air-line and bubbling water surface with algae in suspension is shown in Picture B below. **Oxygen:** May be required if water quality conditions deteriorate, as an emergency measure to prevent death of cultured organisms until parameters return to a favourable state. Different organisms will show different abilities to tolerate deviations from optimal water quality. **Hides:** Some species of fish like to have habitat on which to rest/shelter/hide.

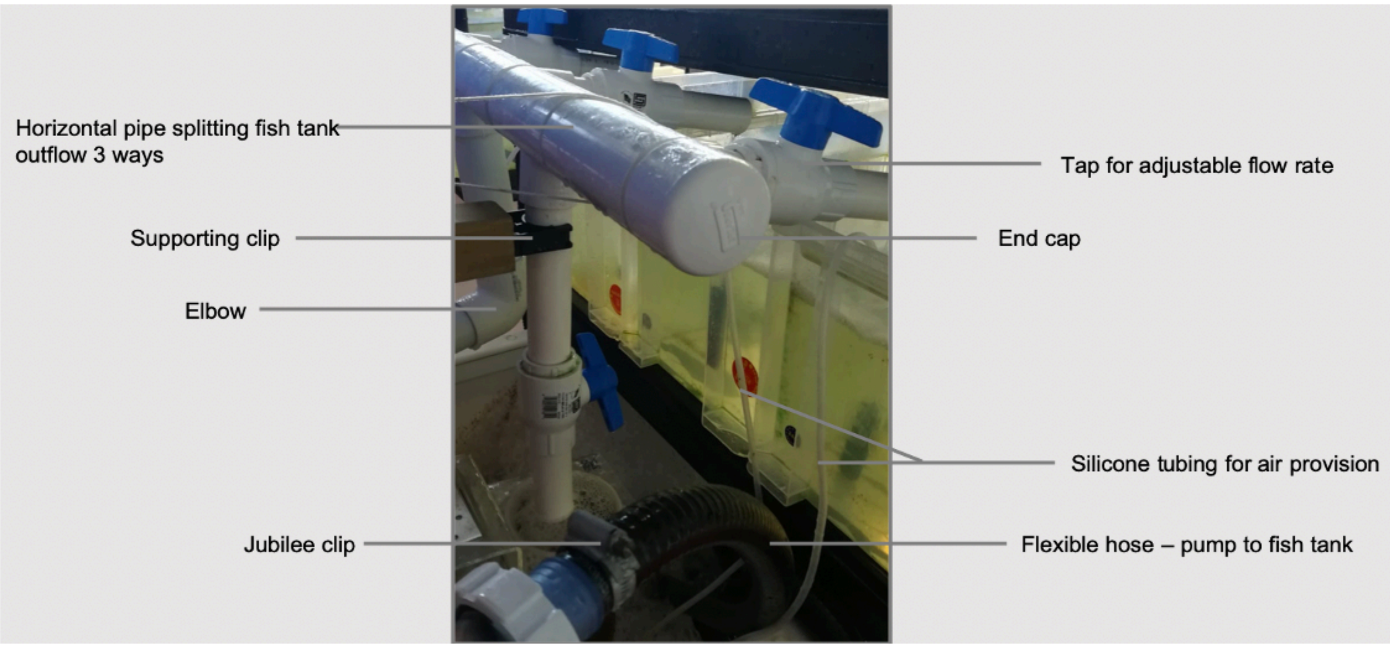
* **Photoperiod:** daylength or number of hours of exposure to illumination per day
Boundary Layer: a thin layer surrounding algal tissue that is chemically altered by the metabolic processes of the seaweed





CONNECTING PIPEWORK - Pipes, tubes and taps:
These pieces provide the connections to put the jigsaw together. Their configuration will be specific to the system that is being built and it may be that several prototypes, with different arrangements and different sized pipes/taps etc. need to be tested before the best solution is found. Prototypes can be tested without gluing the structures in place; once the design is finalised silicone sealant, aquarium cement can be used to permanently fix things.

Above L-R: pvc pipes; t-piece; elbow; ball valve with tap; large ball valve with tap; flexible hose



Above: Example of pipework, tap and hose configuration

Useful Literature

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Lander, T.R., Robinson, S.M.C., MacDonald, B.A., Martin, J.D. (2013). Characterization of the suspended organic particles released from salmon farms and their potential as a food supply for the suspension feeder, *Mytilus edulis* in integrated multi-trophic aquaculture (IMTA) systems. Aquaculture 406 – 407, 160-171.

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