INTEGRATE FACTSHEET 1

General Introduction to IMTA in Recirculating Systems

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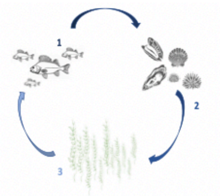
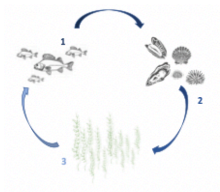




INTRODUCTION

This factsheet is the first of three that will together provide an overview of **integrated multi-trophic aquaculture (IMTA)** in **recirculating aquaculture systems (RAS).** This factsheet (No. 1) provides some definitions and gives general introductions to what IMTA and RAS are. No. 2 gives an overview of how to build a simple recirculating system, and No. 3 gives some indications of what is involved in managing such a system. None of these are comprehensive but can be used as a starting point for further research into this type of aquaculture system.

The information in these factsheets is largely based on **our pilot model of a 2-functional group fish (lumpsucker; *Cyclopterus lumpus*) and seaweed (sea lettuce; *Ulva* spp.) marine partial RAS**.

DEFINITIONS:

Recirculating Aquaculture System (RAS): RAS makes use of mechanical and biological waste treatment systems in order to recycle water. Treatment technologies include solids removal, biofiltration, degassing, oxygenation and disinfection. Water reuse rates are typically > 90 % but can be up to 99 %. RAS differ from **Flow-Through Systems (FTS)** in that in FTS influent water is continuously drawn from the source and flows through the cultivation units before the effluent is returned to the water course. Some systems are **Hybrid (Partial RAS, PRAS),** somewhere between RAS and FTS in nature and are often the result of up-grading traditional FTS, these incorporate some of the water treatment systems of RAS, creating systems with variable water reuse rates.

Integrated Cultivation: This involves the co-cultivation of different species to make use of waste streams from one species to provide resources for another, for example using waste from fish to fertilise seaweeds. There are many examples adapted to different environments and species combinations, and ranging from very traditional, simple and extensive systems to industrialised, technologically complex and intensive. Some examples are integrated agriculture-aquaculture systems (IAAS), aquaponics* and integrated multi-trophic aquaculture (IMTA). These factsheets are concerned with IMTA in RAS: a full definition of IMTA is given below, and some definitions and a generalized schematic are depicted on the following page:

IMTA = Enhanced production of aquatic organisms (with or without terrestrial organisms) of two or more functional groups, that are trophically connected by demonstrated nutrient flows and whose biomass is fully or partially removed by harvesting to facilitate ecological balance.
Project INTEGRATE – IMTA definition

*Aquaponics and IMTA are very similar, however although IMTA can include terrestrial organisms, its core production environment is aquatic. This is different to aquaponics, that uses an aquatic growing medium and aquatic based fertilisation in order to produce predominantly terrestrial crops.

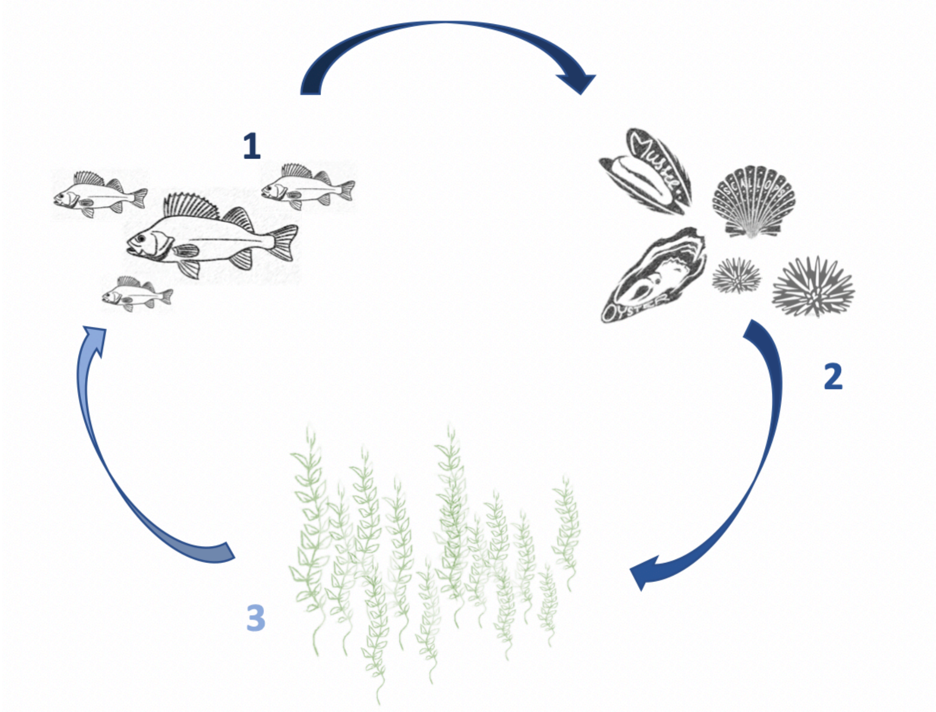
TERMINOLOGY

Functional Group: A group of organisms that share common ecological functions but that are not necessarily related in any phylogenetic way. In the case of IMTA this refers to whether an organism is: 1) provided feed externally (fed species, often high trophic level fish or shrimp), 2) a particulate feeder – either suspension or detritivore, often termed organic extractive species (e.g. bivalves, echinoderms, mullet), or 3) uses dissolved waste, often termed inorganic extractive species (e.g. algae).

Trophic Connection: Organisms have a trophic connection when energy flows between them. This can be when one organism eats another, or more indirectly when an organism utilises waste products from another as a food source e.g. a sea cucumber feeding on the waste feed and faeces underneath finfish cages.

Biomass Removal: This is an important concept within IMTA because the principal aim of IMTA is remediation of excess nutrient inputs to the environment. If nutrients are not removed from the system through harvest then they are merely cycled differently within the system. Nutrient removal itself, and therefore the appropriateness of IMTA, may be more or less necessary depending on the scale of aquaculture and the characteristics of the surrounding environment.

Ecological Balance: The ability of the defined system to maintain itself in a steady state and retain all its functional capacities.



Organisms of a relatively high trophic level **(1),** commonly fish or shrimp, and often a species whose cultivation relies on an external food source are cultivated. Dissolved and particulate waste contained in the cultivation water from these organisms is transferred to the cultivation chambers / location of lower trophic level particulate feeders which remove a proportion of the organic particulate waste **(2)**. Dissolved waste from these organisms then passes to algae or plants **(3)** which remove the dissolved phase of the nutrients thus partially or wholly 'scrubbing' the system of nutrient enrichment and allowing the cleaned water to be re-used in stage **1.**

Key Points

- Mass-balance of energy flow from different functional groups, maximising production efficiency
- The fed species, organic extractive species and/or inorganic extractive species are cultivated in a functional balance in order to maintain a system with good water quality

RECIRCULATING IMTA

SPECIFIC COSTS AND BENEFITS OF IMTA AND RAS

What are the benefits?

Both IMTA and RAS have potential advantages in terms of efficiency of resource use, making them possible sustainable aquaculture options. Combining the two methods aims to improve efficiency further by incorporating the nutrient recycling concept of IMTA with the water recycling concept of RAS.

RAS

The principle advantage of RAS is the control over water quality and the production environment that is achieved. This creates the opportunity for a more intensive production unit that can:

- Utilise higher stocking densities
- Extend the growing season/reduce the time taken for the crop to reach maturity as ambient temperatures are not relied upon
- Greatly reduce water consumption and land footprint
- Produce less volume of more concentrated effluent that is easier to treat
- Allow greater control of biosecurity risks, lessening pathogen transfer between the farm and the environment

However, there are also certain trade-offs, or disadvantages, such as:

- Higher investment and operating costs
- Greater technical complexity
- Increased energy use

IMTA

The principle advantage of IMTA is nutrient (or feed) efficiency. Resources often hitherto regarded as waste (uneaten feed, faeces, urea) are managed *within the system* to provide feed resources for secondary and tertiary, etc., species. IMTA can:

- Increase productivity per unit of feed input
- Increase the biological and economic resilience of the farm by diversification
- Decrease and quantity, and/or change the quality, of nutrients leaving the farm as effluent

But disadvantages include:

- Greater technical complexity and need for knowledge of multiple species
- Current lack of knowledge about species compatibility and trophic interactions
- Greater overall areal farm footprint
- Current lack of a way to efficiently capitalise on the improved nutrient emissions

In both cases the result is greater productivity per unit space (RAS) or per unit energy/feed (IMTA), accompanied by less, and cleaner/different, discharge – in a process known as **sustainable intensification**. Ultimately, system choice will be dictated primarily by the requirements of the species cultivated *and its value*, the desired level of control and the technical know-how to achieve and manage it, and the quality of the available water supply.

Useful Literature

Angel, D., Jokumsen, A., Lembo, G. (2019). Aquaculture Production Systems and Environmental Interactions. Ch. 6 in Lembo, G., Mente, E. (eds) Organic Aquaculture. Springer, Cham. 978-3-030-05603-2

Soto, D. (ed.), (2009). Integrated mariculture: a global review. FAO Fisheries and Aquaculture Technical Paper. No. 529. Rome, FAO, 183p.

ENVIRONMENTAL IMPACTS OF AQUACULTURE/IMTA/RAS

Aquaculture Environment Interactions: By its nature aquaculture interacts with the surrounding environment; *how it does so is dependent on the species being cultivated and the system used to do so*. Industry is constantly improving, and a big focus is on the development of cleaner production practices. Some environmental issues are as follows:

- Alteration/destruction of local habitat for farm creation
- Organic and dissolved nutrient enrichment to recipient water
- Freshwater consumption
- Modification of temperature and flow-rater profiles
- Transmission of diseases and pathogens off the farm
- Chemical and therapeutant contamination
- Fish escapes and genetic pollution
- Use of wild stock for fish meal production or for stocking the aquaculture facility/use as broodstock
- Effects on wildlife that interacts with the farm
- Use of fossil fuels

How does IMTA/RAS impact each of these categories?

The impact of either or both RAS and IMTA on each category will be very specific to each individual operation. One of the problems of assessing aquaculture impacts is this fact. Ideally, life cycle analyses and other broad metrics that take account of multiple factors will be used to assess the overall environmental performance. These are very data intensive and so tend to come after initial research and commercialisation has generated data at a sufficient scale. Few have been carried out to date and so this information is largely lacking.

Intensification versus extensification: Neither type of aquaculture is inherently more or less sustainable per se, but there will be trade-offs between different markers of sustainability. An extensive pond system that uses naturally occurring larvae and food sources may be very sustainable in terms of biotic resources used for feed (i.e. does not use fish meal or fish oil) but may have a very high requirement for space. Sustainable intensification aims to maximise productivity of the system without incurring the negative impacts usually associated with intensification. However, in almost all circumstances there are trade-offs. To give an example, highly intensive salmon smolt production in RAS systems uses less water, less land and produces less effluent, but this comes at the price of very high energy use and this sort of high energy high investment/cost farming also requires a high value species, which tend to be those that have a high protein requirement and therefore often have very high fish meal and fish oil requirements. The sustainability of a certain system is very context, and metric, dependent.

Irish Recirculating-IMTA

- Research: Keywater fisheries; NUIG; UCC; BIM
- Species: lumpsucker, perch, trout, duckweed, sea lettuce
- Systems: pilot scale fish/seaweed tank units; commercial scale pill-ponds and raceways

Mount Lucas: trout, perch and duckweed integrated in a pill-pond/raceway recirculating outdoor cultivation facility, with onsite energy production - **Bord na Mona/BIM**