Integrated multi-trophic aquaculture (IMTA) in marine temperate waters

Kelly Barrington
University of New Brunswick, Department of Biology, PO Box 5050, Saint John, NB, E2L 4L5, Canada

Thierry Chopin
University of New Brunswick, Department of Biology, PO Box 5050, Saint John, NB, E2L 4L5, Canada
E-mail: tchopin@unbsj.ca

Shawn Robinson
Department of Fisheries and Oceans, St. Andrews Biological Station, 531 Brandy Cove Road, St. Andrews, NB, E5B 2L9, Canada

Barrington, K., Chopin, T. and Robinson, S. 2009. Integrated multi-trophic aquaculture (IMTA) in marine temperate waters. In D. Soto (ed.). Integrated mariculture: a global review. *FAO Fisheries and Aquaculture Technical Paper.* No. 529. Rome, FAO. pp. 7–46.

CONTENTS

ABSTRACT

This report covers the present situation and the potential for the practice of integrated multi-trophic aquaculture (IMTA) in the world's marine temperate waters.

IMTA is the practice which combines, in the appropriate proportions, the cultivation of fed aquaculture species (e.g. finfish/shrimp) with organic extractive aquaculture species (e.g. shellfish/herbivorous fish) and inorganic extractive aquaculture species (e.g. seaweed) to create balanced systems for environmental sustainability (biomitigation) economic stability (product diversification and risk reduction) and social acceptability (better management practices).

In summary,

- Canada, Chile, China, Ireland, South Africa, the United Kingdom of Great Britain and Northern Ireland (mostly Scotland) and the United States of America are the only countries to have IMTA systems near commercial scale, or at commercial scale, at present.
- France, Portugal and Spain have ongoing research projects related to the development of IMTA.
- The countries of Scandinavia, especially Norway, have made some individual groundwork toward the development of IMTA, despite possessing a large finfish aquaculture network.
- All countries discussed have enormous potential for IMTA growth and development.

Genera of particular interest and those with high potential for development in IMTA systems in marine temperate waters include:

- *Laminaria, Saccharina, Sacchoriza, Undaria, Alaria, Ecklonia, Lessonia, Durvillaea, Macrocystis, Gigartina, Sarcothalia, Chondracanthus, Callophyllis, Gracilaria, Gracilariopsis, Porphyra, Chondrus, Palmaria, Asparagopsis and Ulva* (seaweeds).
- *Haliotis, Crassostrea, Pecten, Argopecten, Placopecten, Mytilus, Choromytilus* and *Tapes* (molluscs).
- *Strongylocentrotus, Paracentrotus, Psammechinus, Loxechinus, Cucumaria, Holothuria, Stichopus, Parastichopus, Apostichopus* and *Athyonidium* (echinoderms).
- *Nereis, Arenicola, Glycera* and *Sabella* (polychaetes).
- *Penaeus* and *Homarus* (crustaceans).
- *Salmo, Oncorhynchus, Scophthalmus, Dicentrarchus, Gadus, Anoplopoma, Hippoglossus, Melanogrammus, Paralichthys, Pseudopleuronectes* and *Mugil* (fish).

These genera have been selected due to their established husbandry practices, habitat appropriateness, biomitigation ability and economic value.

In order to ensure the expansion of IMTA in these regions several steps should be taken where appropriate. These include:

- Establishing the economic and environmental value of IMTA systems and their co-products.
- Selecting the right species, appropriate to the habitat, available technologies, and the environmental and oceanographic conditions, complementary in their ecosystem functions, growing to a significant biomass for efficient biomitigation, and for which the commercialization will not generate insurmountable regulatory hurdles.
- Promoting effective government legislation/regulations and incentives to facilitate the development of IMTA practices and the commercialization of IMTA products.
- Recognizing the benefits of IMTA and educating stakeholders about this practice.
- Establishing the R&D&C continuum for IMTA.

Taking all these factors into account, IMTA can be used as a valuable tool towards building a sustainable aquaculture industry. IMTA systems can be environmentally responsible,

profitable and sources of employment in coastal regions for any country that develops them properly, especially when government, industry, academia, communities and environmental non-governmental organizations work in consultation with each other.

BACKGROUND AND OBJECTIVES

This report covers the present situation and the potential for the practice of integrated multi-trophic aquaculture (IMTA) in the world's marine temperate waters. The temperate zone of the globe generally refers to the region between latitudes 23.5° and 66.5° in both hemispheres (Milne, 1995). This includes oceanic waters in the temperature range of 7-25°C, although in winter the water temperature can dip to the near freezing point in higher latitudes (Levinton, 1995). This report considers countries in this range, particularly Canada, Chile, Finland, France, Ireland, Norway, Portugal, Spain, South Africa, Sweden, the United Kingdom (mostly Scotland) and the United States of America – all of which have active aquaculture industries and either have small scale IMTA systems already in practice or hold potential for the development of IMTA. The case of China is covered succinctly, as published information on IMTA in that country is difficult to find or accessed. The development of IMTA in China would deserve a review on its own and is beyond the scope of this review.

IMTA is a practice in which the by-products (wastes) from one species are recycled to become inputs (fertilizers, food and energy) for another. Fed aquaculture species (e.g. finfish/shrimps) are combined, in the appropriate proportions, with organic extractive aquaculture species (e.g. suspension feeders/deposit feeders/herbivorous fish) and inorganic extractive aquaculture species (e.g. seaweeds) (Figures 1 and 2), for a balanced ecosystem management approach that takes into consideration site specificity, operational limits, and food safety guidelines and regulations. The goals are to achieve environmental sustainability through biomitigation, economic stability through product diversification and risk reduction, and social acceptability through better management practices.

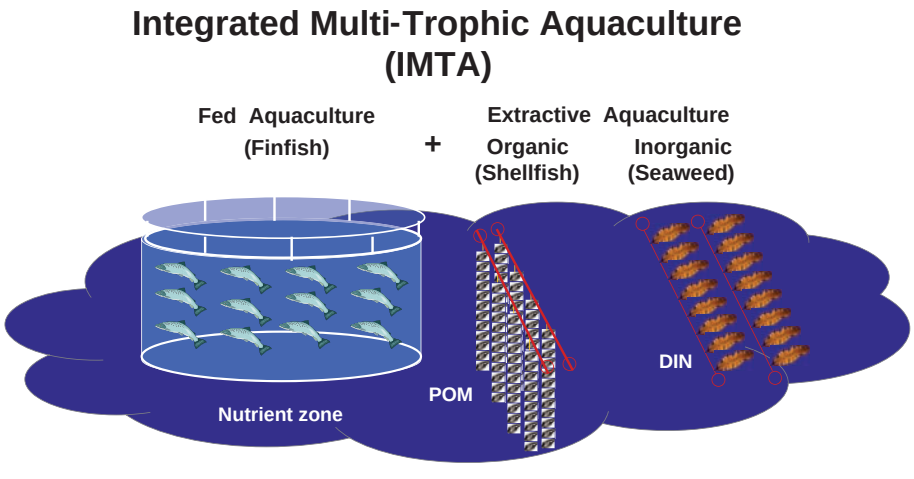
Multi-trophic refers to the incorporation of species from different trophic or nutritional levels in the same system (Chopin and Robinson, 2004; Chopin, 2006). This is one potential distinction from the age-old practice of aquatic polyculture, which could simply be the co-culture of different fish species from the same trophic level. In this case, these organisms may all share the same biological and chemical processes, with few synergistic benefits, which could potentially lead to significant shifts in the ecosystem. Some traditional polyculture systems may, in fact, incorporate a greater diversity of species, occupying several niches, as extensive cultures (low intensity, low management) within the same pond. The *integrated* in IMTA refers to the more intensive cultivation of the different species in proximity of each other (but not necessarily right at the same location), connected by nutrient and energy transfer through water.

Ideally, the biological and chemical processes in an IMTA system should balance. This is achieved through the appropriate selection and proportions of different species providing different ecosystem functions. The co-cultured species should be more than just biofilters; they should also be harvestable crops of commercial value (Chopin, 2006). A working IMTA system should result in greater production for the overall system, based on mutual benefits to the co-cultured species and improved ecosystem health, even if the individual production of some of the species is lower compared to what could be reached in monoculture practices over a short term period (Neori *et al.*, 2004).

Sometimes the more general term "integrated aquaculture" is used to describe the integration of monocultures through water transfer between organisms (Neori *et al.*, 2004). For all intents and purposes, however, the terms "IMTA" and "integrated aquaculture" differ primarily in their degree of descriptiveness. These terms are

FIGURE 1
Salmon (left), mussels (right foreground) and seaweeds (right background) integrated multi-trophic aquaculture (IMTA) in the Bay of Fundy, Canada

FIGURE 2
Conceptual diagram of an integrated multi-trophic aquaculture (IMTA) operation combining fed aquaculture (finfish) with organic extractive aquaculture (shellfish), taking advantage of the enrichment in particulate organic matter (POM), and inorganic extractive aquaculture (seaweeds), taking advantage of the enrichment in dissolved inorganic nutrients (DIN)



Source: Chopin (2006).

sometimes interchanged. Aquaponics, fractionated aquaculture, IAAS (integrated agriculture-aquaculture systems), IPUAS (integrated peri-urban aquaculture systems), and IFAS (integrated fisheries-aquaculture systems) may also be considered variations of the IMTA concept.

The IMTA concept is very flexible. IMTA systems can be land-based or open-water systems, marine or freshwater systems, and may comprise several species combinations (Neori *et al.*, 2004). Some IMTA systems have included such combinations as shellfish/shrimp, fish/seaweed/shellfish, fish/shrimp and seaweed/shrimp (Troell *et al.*, 2003).