Fisheries and Oceans Canada
Pêches et Océans Canada

AQUACULTURE in Canada: Integrated Multi-Trophic Aquaculture (IMTA)

Canada

AQUACULTURE:
Meeting Future Needs

As the human population continues to grow, the need for sustainable food sources also grows. It is expected that traditional fisheries alone will not be able to keep up with the increasing demand for fish, shellfish and marine plants.

Aquaculture (fish farming) already supplies approximately 50 percent of the fish and seafood consumed worldwide, and production is steadily increasing. Further development of the aquaculture industry in Canada could mean significant economic growth as well as job opportunities for Canadians – especially in coastal and rural areas. Responsible growth of the industry will depend on continued research to find innovative ways to improve the environmental performance and diversification of the sector.

Integrated Multi-Trophic Aquaculture: A new approach

Integrated Multi-Trophic Aquaculture (IMTA) is one solution that encourages greater environmental stewardship while increasing economic benefits for growers and communities.

IMTA is a different way of thinking about aquatic food production that is based on the concept of recycling.

Instead of growing only one species (monoculture) and focusing primarily on the needs of that species, IMTA mimics a natural ecosystem by combining the farming of multiple, complementary species from different levels of the food chain.

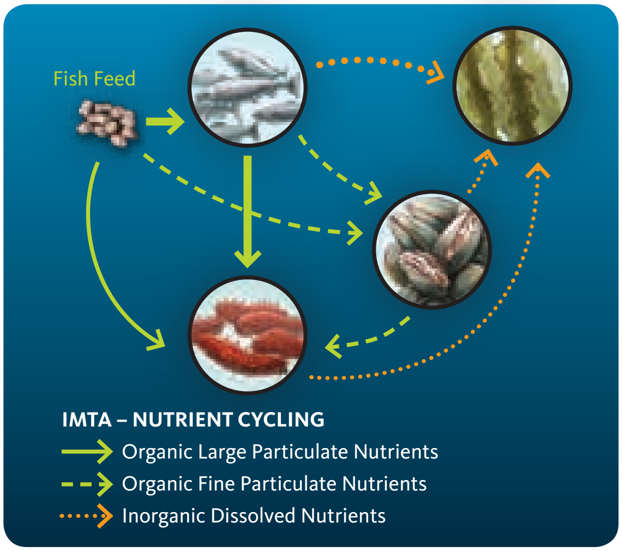
For example, one form of IMTA is to grow fish, invertebrates (like mussels and sea cucumbers) and seaweeds close together for the benefit of each crop and the environment.

HOW IT WORKS

IMTA involves cultivating organisms in a way that allows the uneaten feed, wastes, nutrients and by-products of one species to be recaptured and converted into fertilizer, feed and energy for the growth of the other species. IMTA farmers combine species that need supplemental feed such as fish, with "extractive" species. Extractive species can include filter feeders (e.g., mussels) and deposit feeders (e.g., sea urchins), and seaweeds (e.g., kelps). The filter feeders and deposit feeders use the organic particulate nutrients (uneaten feed and faeces) for nourishment. The seaweeds extract the inorganic dissolved nutrients (such as nitrogen and phosphorus) that are produced by the other farmed species.

Essentially, extractive species act as living filters. The natural ability of these species to recycle the nutrients (or wastes) that are present in and around fish farms can help growers improve the environmental performance of their aquaculture sites. In addition to their recycling abilities, the extractive species chosen for an IMTA site are also selected for their value as marketable products, providing extra economic benefits to farmers.

IMTA mimics a natural ecosystem by combining the farming of multiple, complementary species from different levels of the food chain.



Furthering sustainability through research

THE ROLE OF FISHERIES AND OCEANS CANADA

Fisheries and Oceans Canada (DFO) facilitates the development of sustainable aquaculture in Canada, and sustainability depends on a strong scientific foundation.

Scientists at DFO are examining the development potential for IMTA operations, and how this type of aquaculture could help fish farmers improve fish health and the environmental performance of their operations while maintaining economic viability.

DFO is investing in this research for several reasons: to better understand and regulate the impacts of aquaculture; develop new and enhanced tools and technologies to improve fish health; and to establish sustainable, ecosystem-based practices. DFO is also using the expertise it develops with IMTA to proactively address environmental concerns with the potential scaling up of the industry.

With those objectives in mind, DFO has been involved in a number of IMTA-related research and development activities over several years. These activities fall mainly under three programs: the Aquaculture Collaborative Research and Development Program (ACRDP), the Program for Aquaculture Regulatory Research (PARR), and the Aquaculture Innovation and Market Access Program (AIMAP). Much of this research is being done collaboratively with a number of partners from the aquaculture industry, academia, federal and provincial government departments and agencies, among others.

CANADIAN INTEGRATED MULTI-TROPHIC AQUACULTURE NETWORK

Prompted by the need for a concerted and strategic approach to the development of IMTA throughout Canada, the Canadian Integrated Multi-Trophic Aquaculture Network (CIMTAN) was established under the Natural Sciences and Engineering Research Council (NSERC) Strategic Network Grants program. This network involves 26 scientists from eight universities, six DFO locations and one provincial institution. CIMTAN research centers on areas of environmental system performance and species interactions, system design and engineering, and economic analysis and social implications. CIMTAN is funded by NSERC, DFO, the University of New Brunswick, and four industrial partners: Cooke Aquaculture Inc., Grieg Seafood BC, Kyuquot SEAfoods Ltd., and Marine Harvest Canada Ltd.

DFO IMTA Research Areas

ENVIRONMENTAL SYSTEM PERFORMANCE

Researchers are exploring new cultivation techniques and various infrastructure designs to improve how a site operates, taking into consideration the specific hydrography of each site (e.g., currents, tides, waves). Models are being tested to help scientists predict the dispersal of farm waste and recapture of nutrients needed to achieve the right balance of inorganic and organic extractive species in an IMTA system. This information will help future IMTA sites scale up to commercial production levels.

AQUATIC ANIMAL HEALTH

The influence of IMTA aquaculture practices on wild species, such as the effect of sea lice treatment products on sea worms (polychaetes), is being examined. Innovative research is also being done on filter-feeding bivalves, such as blue mussels, as a possible "green technology" to help control sea lice on farmed fish. By filtering out and ingesting sea lice larvae, they could potentially reduce outbreaks and limit the transfer of diseases, thus improving the overall health of the site and minimizing potential risks to wild species.

POTENTIAL IMTA SPECIES AND SPECIES INTERACTIONS

A variety of new species are being examined to help fill the different feeding niches within an IMTA system.

Part of this research will include looking at the efficiency at which these species can consume – and incorporate into their own biomass – the nutrients produced from aquaculture activities. Species will also be evaluated with respect to the biosecurity of the aquaculture site and how they might help to naturally control parasites and pathogenic viruses and bacteria. This will help reduce the environmental impact of a site, increase profits for the growers and provide consumers with a greater variety of safe products.

The Future of IMTA in Canada:

From Research to Development to Commercialization

Although IMTA in Canada is still largely in its developmental stage, collaborative research results are being used to establish best practices and improve technologies that are already being used on the farm. Products from these activities are also now coming to the market. The ultimate goal of this research is to have these innovative ideas adopted commercially by industry.

IMTA practices will continue to evolve as new research is undertaken and new, innovative solutions to improve these systems are found.

Other IMTA Research Areas

BAY MANAGEMENT

IMTA also involves managing the ecological interactions in and around IMTA sites. Additional research will provide a better understanding of the effects of multiple IMTA sites within a larger bay area, and within the wider context of integrated coastal zone management. This research will also assist management decision-making on how IMTA farmers and other users make use of the resources contained within a given region or area.

OPTIMIZING SPECIES COMBINATIONS

Combinations of co-cultured species will have to be carefully selected according to a number of conditions and criteria: (1) their complementary roles with other species in the IMTA system; (2) their adaptability in relation to the habitat; (3) the culture technologies and site environmental conditions; (4) their ability to provide both efficient and continuous biomitigation; (5) the market demand for the species and pricing as raw material or for their derived products; (6) their commercialization potential; and (7) their contribution to improved environmental performance.

Within an effective IMTA system, peak production may not be achieved for any one species. Rather, the focus would be on optimizing sustainable production and the overall performance of all the combined species.

SPECIES INTERACTIONS

This new research will look at interactions of various IMTA species.

In the context of both disease prevention and disease treatment, there is a potential for shellfish, due to their filtration ability, to reduce viral, bacterial, and/or parasitic diseases in the cultured fish. There may, however, be instances where some species could potentially act as intermediate hosts and thus increase the risk to fish health. Research is needed to better understand and minimize these types of interactions.

Studies will also look at how wild species respond to IMTA species and practices, and the potential effects on their behaviour, growth and reproduction.

IMTA – A balanced, beneficial approach

Integrated Multi-Trophic Aquaculture is an experimental approach for the development of responsible aquatic food production systems, with many possible variations that can be tailored to different regions. It is adaptable for both land-based and offshore aquaculture systems in both saltwater and freshwater environments.

IMTA offers a balanced ecosystem management approach that could benefit growers, the environment and society.

SEE FLIP-SIDE for a poster that illustrates the design of an IMTA system.

ACKNOWLEDGEMENTS

Fisheries and Oceans Canada would like to recognize some of the early pioneers and partners in IMTA research and development including, but not limited to, the following: the Aquaculture Collaborative Research and Development Program (ACRDP) and its collaborators, AquaNet, Atlantic Canada Opportunities Agency Atlantic Innovation Fund, Atlantic Silver Ltd., members of the Canadian Integrated Multi-Trophic Aquaculture Network (CIMTAN), Cooke Aquaculture Inc., Dalhousie University, Grieg Seafood BC Ltd., Heritage Salmon Ltd., Kyuquot SEAfoods Ltd. and SEA Vision Group Inc., Marine Harvest, Memorial University, Natural Sciences and Engineering Research Council (NSERC), New Brunswick Innovation Foundation, Simon Fraser University, University of British Columbia, University of New Brunswick, University of Victoria, Vancouver Aquarium, Vancouver Island University, as well as many other scientists, students and research partners.

Integrated Multi-Trophic Aquaculture (IMTA):
Aquaculture multitrophique intégrée (AMTI) :

Designing an Effective IMTA System

An effective IMTA operation requires the selection, arrangement and placement of various components or species, so as to capture both particulate and dissolved waste materials generated by fish farms.

The selected species and system design should be engineered to optimize the recapture of waste products. As larger **organic** particles, such as uneaten feed and faeces, settle below the cage system, they are eaten by deposit feeders, like sea cucumbers and sea urchins. At the same time, the fine suspended particles are filtered out of the water column by filter-feeding animals like mussels, oysters and scallops.

The seaweeds are placed a little farther away from the site in the direction of water flow so they can remove some of the **inorganic** dissolved nutrients from the water, like nitrogen and phosphorus.

IMTA species should be economically viable as aquaculture products, and cultured at densities that optimize the uptake and use of waste material throughout the production cycle.

SEAWEEDS – THE INORGANIC DISSOLVED NUTRIENT EXTRACTIVE COMPONENT

Kelps and other seaweeds naturally extract dissolved **inorganic** nutrients (e.g., nitrogen and phosphorus) and can help reduce the levels of dissolved inorganic nutrients generated by the other fed and non-fed components of the IMTA system. The seaweed component of the IMTA system is placed a little further away to better capture the inorganic dissolved nutrients that are lighter and travel longer distances than the organic nutrients.

ALGUES MARINES – LES EXTRACTEURS DE NUTRIMENTS INORGANIQUES DISSOUS

Les varechs et autres algues marines extraient naturellement des nutriments **inorganiques** dissous, comme l'azote et le phosphore, et peuvent contribuer à réduire les niveaux de nutriments inorganiques dissous produits par les autres composantes nourries et non nourries du système d'AMTI. Les algues marines du système d'AMTI sont placées un peu à l'écart pour mieux capter les nutriments inorganiques dissous qui sont plus légers et qui sont transportés plus loin que les nutriments organiques.

Farmed Seaweed Species / Espèces d'algues marines élevées :
- **Sugar Kelp** / Laminaire sucrée *(Saccharina latissima)*
- **Winged Kelp** / Alaire *(Alaria esculenta)*

Potential Species / Espèces potentielles :
- **Dulse** / Dulse *(Palmaria palmata)*
- **Sea Lettuce** / Ulve *(Ulva* sp.*)*
- **Nori** / Nori *(Porphyra* sp.*)*

USES OF SEAWEEDS / UTILISATION DES ALGUES MARINES

FOOD FOR OTHER IMTA SPECIES NOURRITURE POUR D'AUTRES ESPÈCES D'AMTI	FOOD FOR HUMANS NOURRITURE POUR LES HUMAINS	PRODUCTS FOR HUMANS PRODUITS POUR LES HUMAINS	CROP FERTILIZER ENGRAIS

FISH – THE FED COMPONENT

Some farmed species, such as salmon and sablefish, require manufactured feeds, small portions of which go uneaten by the fish.

All animals naturally produce **organic** and **inorganic** waste as a result of their feeding and metabolic activities. But when it comes to converting feed into body mass, fish are some of the most efficient organisms – terrestrial or aquatic – that are currently being farmed or cultured.

The wastes produced by fish, which include uneaten feed and faeces, provide high-quality nourishment for other species within the IMTA system – including wild species.

POISSON – LA COMPOSANTE « NOURRIE »

Certaines espèces élevées, comme le saumon et la morue charbonnière, ont besoin d'aliments préparés. Or, une certaine quantité des aliments en question échappe aux poissons.

Tous les animaux produisent naturellement des déchets **organiques** et **inorganiques** dans le cadre de leur alimentation et de leurs activités métaboliques. Les poissons comptent parmi les organismes terrestres et aquatiques élevés par l'homme les plus efficaces lorsqu'il s'agit de transformer les aliments en masse corporelle.

Les déchets des poissons, qui comprennent de la nourriture non consommée et des fécès, représentent des aliments de grande qualité pour d'autres espèces vivant dans le système d'AMTI, y compris des espèces sauvages.

Farmed Fish Species / Espèces de poissons élevées :
- **Atlantic Salmon** / Saumon de l'Atlantique *(Salmo salar)*
- **Sablefish** / Morue charbonnière *(Anoplopoma fimbria)*

Potential Species / Espèces potentielles :
- **Chinook Salmon** / Saumon quinnat *(Oncorhynchus tshawytscha)*

For further information, please visit / Pour obtenir de plus amples renseignements, veuillez visiter :
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A new approach to sustainable fish and seafood production

An Integrated Multi-Trophic Aquaculture (IMTA) farming system combines organisms from different levels of the food chain that normally share the environment – where waste from one species becomes a source of food for another.

IMTA involves farmers cultivating species that need to be fed (such as salmon), with "extractive" species (such as mussels, sea cucumbers, worms and various seaweeds). Extractive species use the **organic** and **inorganic** materials and by-products from the other species for their own growth.

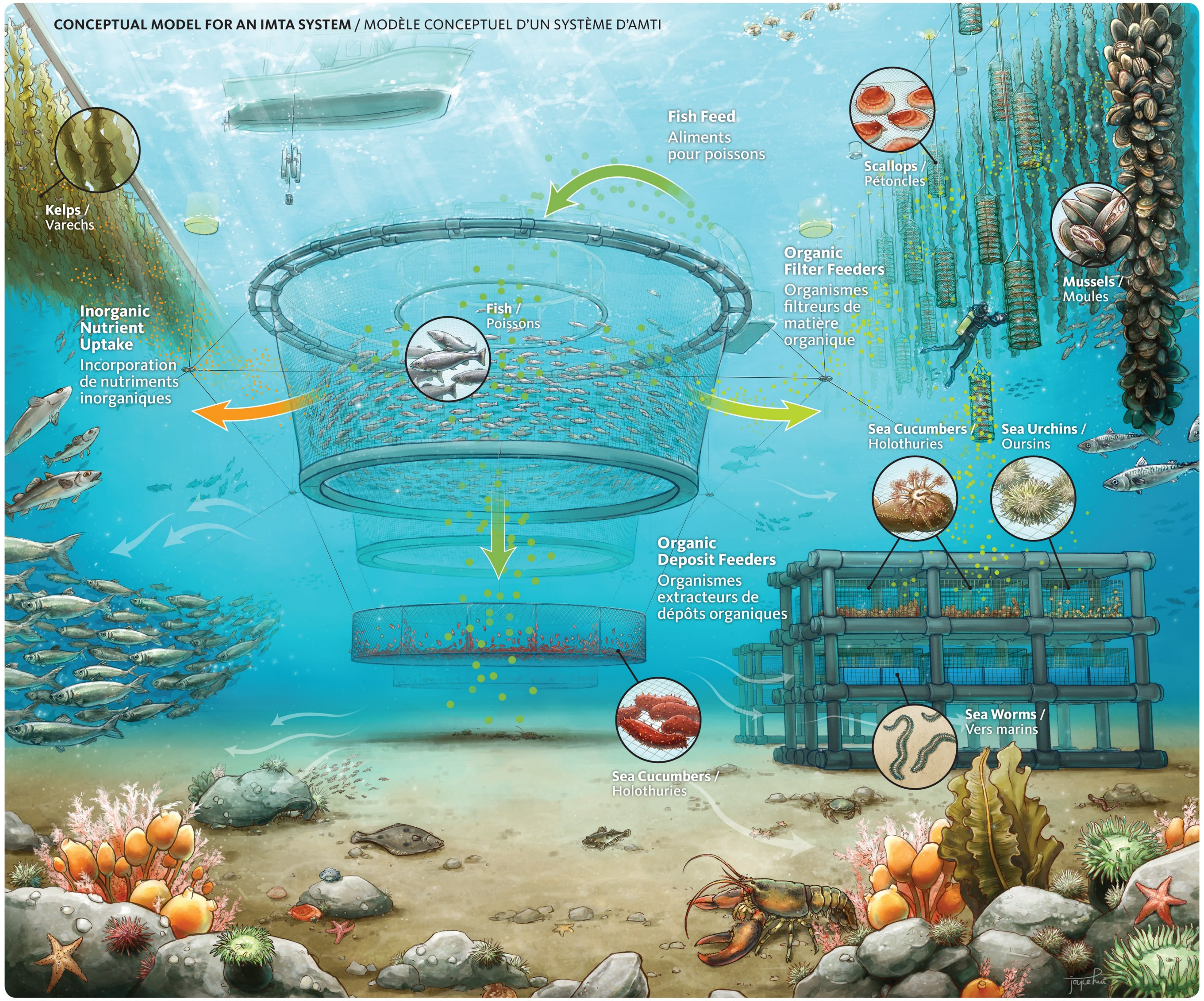
This mix of organisms from different levels of the food chain mimics the functioning of natural ecosystems. By recycling nutrients, this type of balanced system will ultimately provide healthier waters.

Une nouvelle approche à l'élevage durable de poissons, de mollusques, et d'algues

Les systèmes D'AMTI réunissent des organismes appartenant à différents maillons de la chaîne alimentaire qui se partagent habituellement un même environnement. Dans un tel système, les déjections d'une espèce servent de nourriture à une autre.

L'AMTI concerne des producteurs qui élèvent des espèces que l'on doit nourrir (comme le saumon) et des espèces d'« extraction » (comme les moules, les holothuries, les vers polychètes et différentes espèces d'algues marines). Les espèces d'extraction utilisent les matières et les produits **organiques** et **inorganiques** provenant d'autres espèces pour assurer leur croissance.

Cette combinaison d'organismes occupant différentes places dans la chaîne alimentaire imite le fonctionnement des écosystèmes naturels. Ce type de système équilibré, qui repose sur le recyclage des nutriments, contribuera à l'assainissement des eaux.



Inorganic Dissolved Nutrients / nutriments inorganiques dissous
Water Current / courant d'eau
Organic Fine Particulate Nutrients / nutriments organiques à particules fines
Organic Large Particulate Nutrients / nutriments organiques à particules grossières

Concevoir un système d'AMTI efficace

Pour qu'une exploitation d'AMTI soit efficace, il faut sélectionner et disposer plusieurs composantes ou espèces de façon qu'elles puissent attraper les matières particulaires et les déjections dissoutes provenant des exploitations aquacoles.

La sélection des espèces et la conception du système doivent faire en sorte que la récupération des déchets est maximisée. Les organismes limivores, comme les holothuries et les oursins, se nourrissent des particules **organiques** de bonne taille, comme la nourriture non consommée et les fécès, qui se déposent sous les cages. Simultanément, les particules fines en suspension sont extraites de la colonne d'eau par des organismes filtreurs comme les moules, les huîtres et les pétoncles.

On place les algues marines un peu à l'écart du site, dans la direction du courant, de façon quelles extraient une partie des nutriments **inorganiques** dissous dans l'eau, comme l'azote et le phosphore.

Les espèces utilisées dans le cadre de l'AMTI doivent être des produits de l'aquaculture viables sur le plan économique et être élevées à une densité permettant d'optimiser l'utilisation des déchets tout au long du cycle d'élevage.

FILTER FEEDERS – THE ORGANIC FINE PARTICULATE EXTRACTIVE COMPONENT

Filter-feeding bivalves, such as mussels and oysters filter the water column, feeding on micro-algae and small zooplankton and fine particulate matter. They can be used to reduce the level of finer **organic** particles that result from other fed or non-fed components of the IMTA system.

ORGANISMES FILTREURS – LES EXTRACTEURS DE NUTRIMENTS ORGANIQUES À PARTICULES FINES

Les bivalves filtreurs, comme les moules et les huîtres, filtrent la colonne d'eau et se nourrissent de micro-algues, de zooplancton et de particules fines. On peut s'en servir pour diminuer la quantité de particules **organiques** fines provenant de la composante nourrie ou non nourrie du système d'AMTI.

Farmed Filter Feeder Species / Espèces d'organismes filtreurs élevées :
- **Blue Mussel** / Moule bleue *(Mytilus edulis – Mytilus trossulus)*
- **Japanese Scallop** / Pétoncle japonais *(Mizuhopecten yessoensis)*

Potential Species / Espèces potentielles :
- **Sea Scallop** / Pétoncle géant *(Placopecten magellanicus)*
- **Pacific Oyster** / Huître creuse du Pacifique *(Crassostrea gigas)*
- **Basket Cockle** / Bucarde de Nuttall *(Clinocardium nuttalli)*
- **Gallo Mussel** / Moule méditerranéenne *(Mytilus galloprovincialis)*

Did you know? / Le saviez-vous?

When it comes to converting feed into body mass, fish are some of the most efficient organisms—terrestrial or aquatic—that are currently being farmed or cultured. / Les poissons comptent parmi les organismes terrestres et aquatiques élevés par l'homme les plus efficaces lorsqu'il s'agit de transformer les aliments en masse corporelle.

DEPOSIT (OR BOTTOM) FEEDERS – THE ORGANIC LARGE PARTICULATE NUTRIENTS EXTRACTIVE COMPONENT

Under an IMTA model, these are primarily invertebrates – such as sea cucumbers, sea urchins and certain worm species – that sift through sediment to feed on **organic** particulate matter. They can be used to recycle the larger organic particles, that result from the other (fed or non-fed) components of the IMTA system, and that settle beneath the farm site.

ESPÈCES LIMIVORES – LES EXTRACTEURS DE NUTRIMENTS ORGANIQUES À PARTICULES GROSSIÈRES

Selon le modèle d'AMTI, ces espèces sont surtout des invertébrés, comme les holothuries, les oursins et certaines espèces de vers polychètes, qui fouillent les sédiments à la recherche de particules **organiques**. On peut s'en servir pour recycler les particules organiques grossières provenant de la composante nourrie ou non nourrie du système d'AMTI qui se déposent sous l'exploitation aquacole.

Farmed Deposit Feeder Species / Espèces limivores élevées :
- **Green Sea Urchin** / Oursin vert *(Strongylocentrotus droebachiensis)*
- **California Sea Cucumber** / Holothurie du Pacifique *(Parastichopus californicus)*

Potential Species / Espèces potentielles :
- **American Lobster** / Homard américain *(Homarus americanus)*
- **Clam Worm** / Néréide *(Nereis virens)*
- **Blood Worm** / Ver de vase *(Glycera dibranchiata)*
- **Northern Sea Cucumber** / Holothurie du nord *(Cucumaria frondosa)*
- **Red Sea Urchin** / Oursin rouge *(Strongylocentrotus franciscanus)*

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