Fisheries and Oceans Canada
Pêches et Océans Canada

Aquaculture Collaborative Research and Development Program (ACRDP) Fact Sheet

Issue 11
May, 2012

Pre-Commercial Integrated Multi-Trophic Aquaculture (IMTA) in Coastal British Columbia

Summary

Integrated Multi-Trophic Aquaculture (IMTA) is an aquaculture approach that employs a combination of economically-viable aquaculture species to facilitate the interception, extraction, and use of waste components of a finfish farm. The goal of IMTA development is to create balanced systems for environmental remediation, economic stability, and social acceptability to support the sustainable development of aquaculture. Research on IMTA is on-going on both coasts of Canada to examine the commercial feasibility and to maximize the ecological benefits of the concept. At Kyuquot SEAfoods Ltd. in British Columbia a comprehensive research program is underway to apply this concept to culture operations. This project addressed three distinct technical issues crucial to the commercialization of the IMTA approach. First, the deposit-feeding sea cucumber (*Parastichopus californicus*), which naturally consumes organic material on the seabed, was shown to readily consume sablefish faeces and uneaten feed and exhibited good growth and survival rates on this waste material. Second, the development and testing of a unique shellfish production system, compatible with the finfish rearing infrastructure, demonstrated that this new grow-out system is a stable and highly productive platform for the production of multiple shellfish species. Third, the growth phase and overall productivity of the kelp component of the IMTA system was extended using an early, controlled stocking of kelp seed.

Introduction

Integrated Multi-Trophic Aquaculture (IMTA) has been introduced as a viable aquaculture development option for Canada. Research is ongoing on both coasts to test this concept on a commercial scale. IMTA is an advanced aquaculture system approach which combines the cultivation of fed aquaculture species (e.g., salmon, sablefish) with organic extractive aquaculture species (e.g., mussels, oysters, scallops) and inorganic extractive aquaculture species (e.g., kelp) to create balanced systems for environmental sustainability, economic stability, and social acceptability.

The design of an effective IMTA system requires selection and placement of species that intercept both particulate and dissolved waste materials that are generated by the finfish farm. The selected species and system design should be such that the uptake of waste products is maximized. Large organic particles (excess feed and faeces) settle below the cage system to be utilized by deposit feeders (e.g., sea cucumbers), while smaller suspended waste particles are filtered out of the water column by filter-feeding animals (e.g., oysters, mussels, scallops) placed in proximity to the finfish cages. The seaweed component is placed further away from the farm site in the direction of water flow so that excess dissolved nutrients can be removed from the water. It is important that selected species are economically viable as aquaculture species and that they be cultured at densities that maximize the uptake and use of waste material continuously over the finfish production cycle.

A number of issues arise in attempting to satisfy basic IMTA requirements in a commercial system. Kyuquot SEAfoods Ltd., on northwest Vancouver Island, British Columbia is taking a comprehensive approach to making

IMTA commercially viable. This study was designed to assess:

- Sea cucumbers' ability to utilize settleable organic solids beneath a finfish farm;
- Modification of a steel net cage system to integrate an effective, commercial-scale shellfish (extractive) component;
- The success of introducing kelp seed year-round to ensure functioning of the IMTA inorganic extractive component all year long.

Methods

Sea Cucumber Study

This project comprised a combination of laboratory and farm-based experiments and trials. The initial phase of the project was conducted at the Pacific Biological Station (DFO) in Nanaimo, BC and focused on faecal material consumption and feeding rates (Figure 1).

Controlled experiments were conducted using juvenile (<6 cm length) and adult (>6 cm length) sea cucumbers (*Parastichopus californicus*) which were fed either fresh sablefish faeces or natural sediment. Faecal production rates of the two size classes were measured at temperatures of 4, 8, 12, and 16°C, a range anticipated to be encountered on the farm site.

Results of the laboratory-based experiment were used to design an in situ trial at the Kyuquot SEAfoods IMTA farm site to test sea cucumber performance in a production setting. A 1x15 m aluminum frame system was used to hold trays of juvenile (7–99 g wet weight) and adult (100–565 g wet weight) sea cucumbers at low, medium, and high density (12.4, 16.8, and 21.2 individuals m^{-2}, respectively) directly beneath the cultured sablefish and well above the seafloor (negating the ability of the sea cucumbers to feed on natural organic material on the benthos). The culture units were maintained for one year with sea cucumber growth and survival monitored approximately every two months.

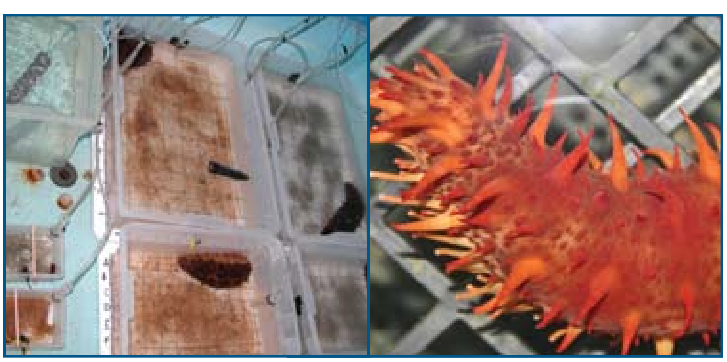

Figure 1.
Sea cucumber (*Parastichopus californicus*) experimental trials to determine consumption rates on sablefish faeces.

Shellfish Infrastructure Development

This project examined how to best incorporate an IMTA shellfish component into a finfish cage system typical of the west coast. Material use, integration, floatation, functionality, and cost-effectiveness considerations were used in the design. A commercial prototype module was constructed and deployed at the IMTA farm and used to assess operational performance over two years.

Kelp Seasonality Study

Mature kelp (*Saccharina lattissima*) fronds were collected from the shoreline of the farm site in the early autumn of each year. Spores from the mature kelp were released into aquaria of sterilized seawater containing PVC spools wrapped with twine. The spores, when ready to settle, metamorphose into small gametophytes and attach to the twine. With full-spectrum light (16:8 photoperiod), gentle water aeration, 2-week nutrient replenishment, and a fixed temperature (10°C), a 6–8 week growth period resulted in kelp seed that were ready to be deployed in the field for on-growing and eventual harvest.

To manipulate and extend the timing of kelp seed deployment on the farm year-round, the aquaria were covered and exposed only to red light at the early-gametophyte stage, suspending gametophyte growth until full-spectrum light was re-introduced. Commercial lines of kelp established over the year were monitored for production performance in the field.

Results

Sea Cucumber Study

Laboratory results showed that sea cucumbers readily consumed sablefish faecal material. Significantly higher faecal production rates were observed when juvenile or adult sea cucumbers were fed natural sediment compared to sablefish faeces (Figure 2). Juvenile sea cucumbers had significantly higher faecal production rates (per unit body weight) than adults when fed either substrate and there was an increase in faecal production rate with increasing temperature up to 12°C.

In the field trial, juveniles grew significantly faster than adults, the former increasing in whole wet weight by 27–56% over the 12 months and the latter decreasing in wet weight by 10–33% over the same time period. It was concluded that adult stocking densities were probably too high to produce net positive growth. Stocking density had a significant effect on both juvenile and adult growth with lower densities producing significantly higher growth rates. The juvenile sea cucumbers cultured under the net pens had a high survival rate (99.5%) and their feeding reduced the total organic carbon and total nitrogen of the sablefish faeces by an average of 60% and 62%, respectively, demonstrating their potential as an important component in IMTA.

Shellfish Infrastructure Development

The shellfish prototype component of Kyuquot SEAfoods' SEAfood System™ (patent-pending) comprises a 200x15 m galvanized steel walkway system with increased floatation over that of traditional fish-cage designs. The system facilitates the use of a greater proportion of the water column and the integration of multiple species by supporting two tiers of shellfish culture apparatus. The upper five meters of the water column currently supports oysters while the water column below (6–15 m) is used for scallop culture. A moving SEA-Tram system, with a cross-cage moving gantry (Figure 3), was designed to facilitate on-system and vertical handling of shellfish. The high tower and six winches of this design feature allow handling of multiple lines and specific layers of vertical production without removal and disruption of others. Operation of this system provides increased efficiencies over traditional shellfish rafts; fuel costs alone for service vessels result in a saving of over $0.23/dozen oysters produced.

Kelp Seasonality Study

Staggering kelp seed deployment was effective in allowing seed to be deployed over three seasons; winter, spring, and autumn. During kelp grow-out, three stages of growth are identifiable: (i) the Pre-Growth Phase, corresponding to a period during which little kelp blade growth occurs, and therefore little nutrient removal capacity is present; (ii) the Growth Phase, characterized by rapid kelp blade elongation with nutrient removal capacity at its greatest; and (iii) the Harvest Phase during which the kelp blades experience elongation, although nutrient removal is at a reduced capacity as concurrent kelp blade erosion is occurring. The duration of each of these growth phases by season of seed deployment is illustrated in Figure 4.

Natural spore release, settlement, and the preparation of seeded kelp lines in an aquaculture context typically occurs in the winter. The growth phase is triggered in the spring by a combination of appropriate photoperiod and nutrients, lasting at least three months. In this study the controlled release of spores and seeding of lines in the autumn resulted in an extended growth phase,

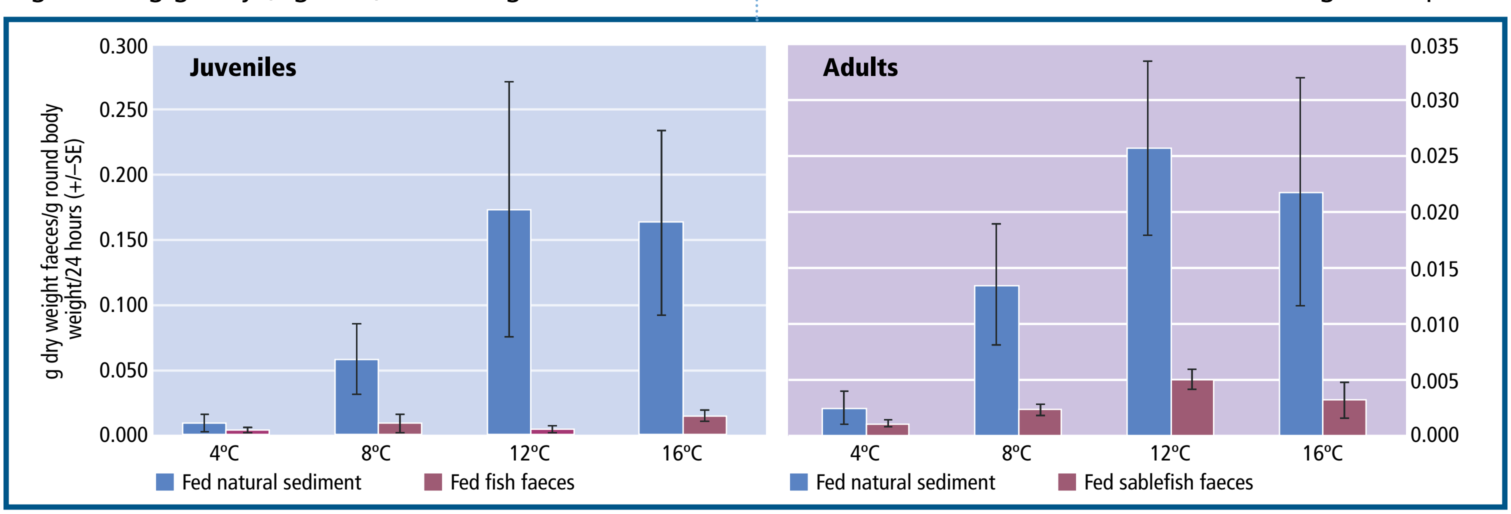

Figure 2.
Faecal production rates of juvenile and adult sea cucumbers (*Parastichopus californicus*) fed sablefish faecal material or natural sediment under different temperature regimes (4, 8, 12, and 16°C).

Figure 3.
The shellfish component of the Kyuquot SEAfoods SEAfood System™, specifically showing the SEA-Tram and its gantry on the new floatation structure.

beginning in early February and provided an additional two months of growth. When seed were deployed in the spring, kelp growth was significantly shortened, likely as a result of light limitation.

Conclusions

Sea Cucumber Study

This research demonstrated that sea cucumbers are effective consumers of sablefish wastes. When fed exclusively on sablefish faeces (and uneaten feed), juvenile sea cucumbers showed excellent growth and survival and were capable of reducing the total organic carbon and nitrogen content in the waste material. The high market value and demonstrated functional performance of this deposit-feeder makes it an excellent addition to the multi-species IMTA production model.

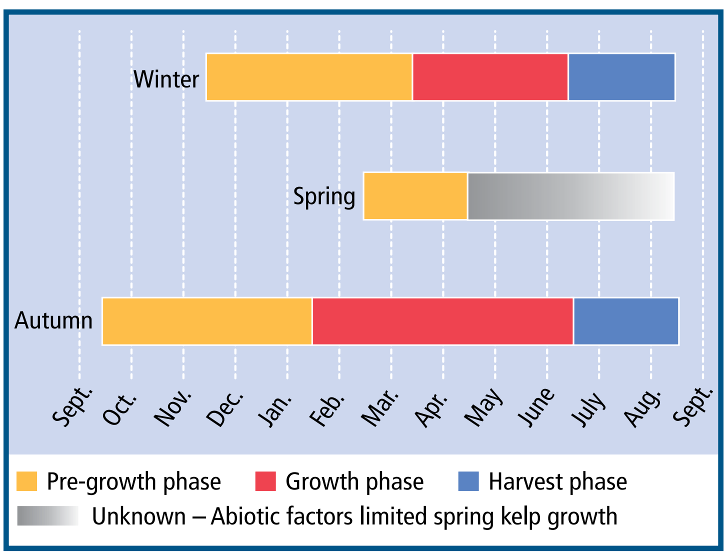

Figure 4.
Summary of kelp growth as a result of three controlled seasonal deployments of seeded lines.

Shellfish Infrastructure Development

The shellfish component of the unique SEAfood System™ provides a stable and highly productive platform for the production of multiple species of shellfish. Higher capital costs for integration of this system component are offset by reduced operational and maintenance costs and increased production through a greater use of the water column.

Kelp Seasonality Study

Use of a single species of seaweed within an IMTA system currently relies upon its natural production cycle. This study demonstrated that a prolonged kelp growth phase can be achieved by using a controlled seed entry and stocking kelp 2–3 months earlier than previously documented. The earlier stocking and extended growth phase should provide an estimated 40% increase in the extractive capacity (and farm production) achieved. This, combined with the selection of complementary seaweed species with varying production timelines will ensure that an IMTA farm maintains an inorganic extractive component for most (if not all) of the year.

This ACRDP project (P-07-01-004) was a collaborative effort between the Department of Fisheries and Oceans (DFO Science) and Kyuquot SEAfoods Ltd. The lead scientist, Dr. Stephen Cross, can be contacted at **sfcross@office.geog.uvic.ca**. The DFO collaborating scientist, Dr. Chris Pearce, Pacific Biological Station, can be reached at **Chris.Pearce@dfo-mpo.gc.ca**. Photos are courtesy of S.F. Cross and Kyuquot SEAfoods Ltd.

For further information on this and other ACRDP projects, visit:
www.dfo-mpo.gc.ca/science/aquaculture/acrdp-pcrda/main_e.htm.

Published by:
Aquaculture Science Branch
Fisheries and Oceans Canada
Ottawa, Ontario K1A 0E6

DFO/2012-1824
Cat No.: Fs23-580/2-2012E-PDF
ISSN 1919-6806 (Print)
ISSN 1919-6814 (Online)
ISBN: 978-1-100-20660-8

French version and alternative formats available through:
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-fra.htm