Integrated Multi-Trophic Aquaculture:
A Workshop
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Abstracts and Biographical Sketches

Sustainable Ecological Aquaculture (SEA) System Development in Western Canada – the Path from Research to Commercialization of IMTA

Stephen F. Cross
Coastal Aquaculture Research & Training (CART) Network, University of Victoria, 3800 Finnerty Rd., Victoria, British Columbia, Canada V8W 3P5
SEA Vision Group, 2541 Conrad Rd., Courtenay, British Columbia, Canada V9N 9N8

Canada continues to take a leading role in the development of Integrated Multi-Trophic Aquaculture (IMTA) systems. In coastal British Columbia the Sustainable Ecological Aquaculture (SEA) System approach integrates IMTA with other sustainability components in an effort to address a variety of the environmental and socio-economic challenges affecting traditional open netcage (finfish) aquaculture. From concept to commercialization, the SEA-System has evolved from a 9-year path of baseline research and initial performance trials on a pilot-scale. Kyuquot SEAfoods Ltd. – part of our SEA-Vision Group of companies - became the first licensed IMTA producer in the province in 2007 and is currently investing in the commercial development of a vertically integrated SEAfarm operation on the northwest side of Vancouver Island. Our first SEAfarm site is dedicated to ongoing commercial-scale R&D, and currently represents a west coast component of a pan-Canadian research initiative on IMTA. Dr. Cross will present some of the background research leading to this avenue of system development for open netcage aquaculture (Presentation 1), the business and environmental arguments supporting the *SEA-vision* we are pioneering for our future coastal aquaculture industry (Presentation 2).
Dr. Cross received his M.Sc. at the University of Victoria in marine quantitative ecology and his Ph.D. at the Aquaculture Institute, University of Stirling (Scotland). Although primarily a private-sector research scientist - who has worked with the aquaculture industry for the past 24 years (President and CEO of the SEA-Vision Group of Companies) - he is also an Associate Professor and Director of the Coastal Aquaculture Research & Training (CART) Network at the University of Victoria in western Canada. His developing research program and commercialization efforts focus on the design and testing of integrated multi-trophic aquaculture systems - a Sustainable Ecological Aquaculture approach to aquatic food production.

Dr. Cross is a current Director on the boards of the Canadian Aquaculture Industry Alliance, the British Columbia Shellfish Growers Association, the Pacific Sablefish Association, the Pacific Organic Seafood Association, and the Land-based Aquaculture Association of Western Canada. He is also President/CEO of the Pacific SEA-Lab Research Society, a not-for-profit that provides a working linkage between the aquaculture industry and academic research communities – with a focus on sustainable approaches for aquaculture.

IMTA Systems Modeling

Joao Ferreira
IMAR - Institute of Marine Research, http://www.ecowin.org, IMAR - Centro de Modelação Ecológica, Dept. Ciências e Engenharia do Ambiente, Faculdade de Ciências e Tecnologia, Quinta da Torre 2829-516 Monte de Caparica, PORTUGAL Tel: +351-21-2948300 EXT 10117, http://www.fojo.org

Joao Gomes Ferreira is a Professor in Environmental Engineering at the Faculty of Sciences and Technology of the New University of Lisbon, Portugal, and currently on the Board of IMAR. He has coordinated the modeling component of 12 European research projects over the last 15 years, published over 40 papers in peer-reviewed journals, and is the author of the EcoWin2000 ecological modeling package and the FARM carrying capacity model.

Finfish in an IMTA context

Michael Rust
NOAA, Northwest Fisheries Science Center, Resource Enhancement and Utilization Technologies Division, 2725 Montlake Blvd E. Seattle, WA 98102

Finfish represent the only fed component of most IMTA systems and thus represent the only human provided input of nutrient energy to the system. In their role within an IMTA system, fish provide dissolved and particulate nutrients, acid and ORP reducing compounds to the other component organisms, and revenue to the business. The quantity and form of these nutrients is dependent on species, size and feed formulation among other factors. Feed formulation provides perhaps the most obvious route for fish effluent modification for the extractive components, conversely, other trends in the aquafeeds industry may impact fish effluent quality for an IMTA system. There is a distinction between IMTA systems that are open to the environment (cage based) and semi-closed to the environment (recirulation aquaculture systems). In most open systems the environment is both necessary and sufficient to rear extractive organisms, while in contrast the semi-closed systems require much tighter coupling of the different tropic levels under cultivation. Fish species selection for open and closed systems would likely differ to take advantage of each systems' unique characteristics in order for the business to be profitable.

Feed Inputs for Aquaculture: Soybean Industry's Perspective

Steven Hart, Ph.D.
Indiana Soybean Alliance, 5730 West 74th Street, Indianapolis, Indiana, sdhart@indianasoybean.com

The United States soybean checkoff organizations recognize that aquaculture is the fastest growing form of animal livestock production in the world today. As world population and demand for seafood continues to increase, the need for feed-based aquaculture will continue to grow rapidly. The soybean checkoff organizations started the Soy-in-Aquaculture (SIA) program in 2002 in order to focus their research and investment in the industry. SIA uses a linear approach to replacing fish meal usage in aquafeeds. Basic research is conducted to determine nutritional requirements and soy-inclusion levels, followed by applied research with practical feed formulations. Once diets are developed, feeding demonstrations with public and private sector collaborators are conducted to increase acceptance of soy-based feed technology. A specific example of this approach is being done by the Indiana Soybean Alliance and their approach to yellow perch aquaculture in the Midwest. Basic nutritional research was conducted to develop an essential amino acid profile for yellow perch. Once this research was conducted, practical diets were formulated and are currently being tested with a private partner, Bell Aquaculture, LLC.

Originally from Toledo, Ohio, Steven Hart moved to Indiana in 2002 to pursue a Ph.D. in fish nutrition from Purdue University. His research background is the development soy-based feeds as an alternative to fish meal-based diets for use in aquaculture. In 2007, Dr. Hart left academia to join the Indiana Soybean Alliance (ISA) as their Director of Aquaculture. Some of the initial work conducted by Dr. Hart and ISA was to determine the market opportunities for locally raised, soy-fed fish. The results of the *market research were very encouraging, determining that there is a strong demand for locally raised, farmed fish. While Dr. Hart was exploring market opportunities, he also began forming strategic partnerships to promote soy-based feeds. By partnering with universities, federal agencies, private farms and other agricultural commodity groups, ISA has taken basic nutritional research and applied it to practical situations through the development of a soy-based yellow perch feed. This feed is currently being tested in the largest commercial yellow perch farm in the U.S., Bell Aquaculture of Redkey, Indiana. After three years of committed aquaculture work, Dr. Hart and ISA continue to put major efforts into developing the industry. In addition to developing new feeds, ISA is also working to better understand the real market opportunity for domestic aquaculture in the U.S. The development of a sustainable business model for the burgeoning aquaculture industry in Indiana and the rest of the U.S. is a major research priority.*

Production Methods and Modeling for Marine Macroalgae Aquaculture

Dr. Doug Ernst
NaturalShrimp Corporation, 502 Robinhood PL, San Antonio, TX 78209, dernst@NaturalShrimp.com, www.NaturalShrimp.com, www.AquaFarm.com

Seaweed farming methods and applications are reviewed and a production model for marine macroalgae is described. A review of seaweed farming shows that global production is dominated by Asian countries using historical, relatively extensive, open-water production methods. Commercial uses of this seaweed are predominately food products and hydrocolloids. Production of marine macroalgae in intensive mono- and poly-culture aquaculture systems is a relatively recent development. Given higher algae production costs for intensive systems, the focus is on higher value algal products, resource and economic synergies of integrated systems, and facility product diversification. For integrated multi-trophic aquaculture (IMTA), macroalgae culture is used as a photosynthetic counterpart to animal respiratory processes. Macroalgae are highly efficient at nutrient uptake (carbon dioxide, nitrogen, and phosphorous) and can provide biofiltration for water recirculation and tertiary wastewater treatment. To support the design and operation of macroalgal production systems and IMTA facilities, a primary productivity and growth model for marine macroalgae is described. Gross primary productivity (GPP, g C m^{-3} d^{-1}) is a function of the maximum growth potential of an algal species or cultivar, algal biomass density, incident solar radiation (or artificial light), water temperature, salinity, pH, and nutrient concentrations (C, N, and P). Nutrient utilization kinetics includes short-term luxury uptake and use of internal nutrient reserves. Net primary productivity (NPP, g C m^{-3} d^{-1}) is equal to GPP minus respiration. Rates of nutrient uptake, metabolite excretion, and algal growth are related to NPP based on algal composition and their stoichiometric relationships to carbon. The model is applied to specific algal cultivars and culture systems by the use of species and site specific model parameters and input variables. Example applications of the model to macroalgae system design and management are provided, using aquaculture simulation software (AquaFarm©).

Doug Ernst has been working in aquaculture for over 30 years, including commercial research and development, systems engineering and modeling, production management, and education. His work has included a range of system types, including solar algae ponds, flow through, recirculating, biofloc, and integrated plant-animal systems. Doug's current position is with NaturalShrimp Corporation (TX), developing intensive production systems for marine shrimp. Prior positions include marine macroalgae production (WA), aquaculture systems modeling, simulation, and database applications (Oregon State University), aquaculture extension and instruction (OSU), development of seawater production systems for tilapia (Bahamas and FL), and salmon ranching (OR). Current work also includes development of aquaculture simulation software for facility design and management planning. Doug received his doctorate from Oregon State University.

IMTA Components: Filter Feeders

Peter Becker
Olympic AquaFarms, P.O. Box 2978, Sequim, WA, 98382, 360-790-5770, becker@olympicaquafarms.com

In Integrated Multi Trophic Aquaculture Systems (IMTA), filter feeders typically serve as the second element in order after the primary producer. While the primary producer is typically a species of finfish, it also maybe a crustacean (ie. shrimp). What determines the selection of the filter feeder component is likely the source and type of particulate first; the ecological or trophic interactions of the filter feeder second, and the marketability of the filter feeder third. Secondary economic considerations like per unit market value of the filter feeder are only significant if the filter feeder works efficiently and there is usually a market for protein. Fortunately, sufficient data exists about fish and shellfish particulate and dissolved waste components. Likewise, there is a rich data set of characteristics of filter feeder food selectivity allowing engineering rather than empirical selection of an IMTA system filter feeder. We give an example of a successful IMTA system that was engineered from specifically selected components: ecological, economic and mechanical, not just from available components.

Peter Becker is an aquaculturist and oceanographer with over 35 years of experience. He holds a Doctorate in physical oceanography and has been employed in applied and theoretical research and development activities world wide. He has worked as an independent consultant in aquaculture systems development and as an auditor/evaluator of aquaculture businesses for international investor groups while a senior research scientist for Battelle Marine Sciences Laboratory in Sequim, WA. He is the founder and owner of aquaculture businesses in shellfish aquaculture (Little Skookum Shellfish Growers LLC, Shelton WA) and finfish aquaculture (Olympic Aquafarms/BPS Industries Inc.) in Washington State, and he is involved as well in a marine products processing business in New Zealand. Between 2000 and 2004 he was chairman the Marine Cluster for the Clallam County Economic Development Council. He is currently the chairman of the West coast aquaculture industry group, the Pacific Aquaculture Caucus Inc. and is the president of the new Olympic Peninsula Loop Culinary Tourism Association Inc. He brings over 10 years experience in the distribution and marketing of fresh live seafood, particularly clams and oysters, to fine restaurants in the United States in Europe. He has been working for several years to solve to the problems in the logistics of economically distributing local, fresh seafood products from his own and other small farms on the Olympic Peninsula to the many small local restaurants around the Olympic Peninsula Loop. He is married with two grown children and lives in Port Angeles, WA.

Integrated multi-trophic aquaculture system components: deposit feeders

Jack Ganzhorn
Fisheries and Aquaculture Program, Peninsula College, 1502 E. Lauridsen Blvd., Port Angeles, WA 98362, jganzhorn@pencol.edu

In a sense, integrated multi-trophic aquaculture (IMTA) systems seek to fabricate a facsimile of natural aquatic ecosystems by utilizing species with different trophic functions. It stands to reason then, that species that utilize particulate organic matter or detritus would be included in IMTA systems because detritus and detritivory are major elements of aquatic ecosystems. This presentation will focus on the factors associated with the incorporation of deposit feeders which are species that utilize settleable detritus. Aquaculture systems produce detritus in forms such as uneaten feed and feces that are either collected onsite for later removal or dispersed to the environment for assimilation by a host of organisms that naturally colonize near the farm. Integrated multi-trophic aquaculture systems internalize this ecological process of assimilation with a view to producing additional crops; turning the waste stream into a revenue stream. Settleable solids from aquaculture contain significant nutritional value for deposit feeders and some species of deposit feeders have significant value for harvest thus providing for additional crops. The amount and fate of settleable solids from aquaculture operations is determined by many factors associated with the feed, site, and species reared. Various detritivorous fish and invertebrate species have been used in marine aquaculture systems; however, sea cucumbers have been of particular interest in IMTA operations that integrate them with fish and shellfish cultivation, either separately or in combination. Sea cucumbers are echinoderms that are highly valued for food and medically valuable bioactive triterpene glycosides. They have been cultivated in Asia for some time; however, there use in intensive IMTA is more recent. In freshwater aquaculture, there is long history of detritivore use in traditional extensive aquaculture; however, intensive aquaculture systems typically require biosolids removal and separate treatment. Opportunities exist for incorporation of these biosolids in IMTA systems.

Jack has taught the fisheries and aquaculture program at Peninsula College since 1990. His teaching responsibilities include courses in fish biology, fisheries ecology and aquaculture. Jack has been working on developing the fisheries and aquaculture curriculum to articulate with the college's Bachelor of Applied Science degree that combines a technical background in aquaculture with applied business skills and knowledge. Currently, he is conducting a sabbatical study of sustainable aquaculture practices which involves curriculum development and project collaboration. Jack has a Masters of Agriculture from Oregon State University that emphasized fish health and was Manager of Technical Services at Oregon AquaFoods Inc., a large salmon ranching operation, prior to coming to Peninsula College.

Biosecurity considerations in an IMTA Health Management Plan

Grace A. Karreman

Biosecurity can be defined as a system of measures (i.e., inputs, movements and other activities), each with a set of procedures, that taken together minimize the risk of introduction and spread of infectious organisms within or between aquatic animal populations. Biosecurity is based on risk assessment methodology and includes three key areas:

1. Bioexclusion (prevention of pathogen entry)
2. Within-site infectious disease control (management of pathogens within a facility)
3. Biocontainment (prevention of pathogens release)

Planning for an IMTA facility must include a Health Management Plan. Using a salmon farm as an example, the presentation will analyse additional health issues that should be considered in an IMTA facility.

Dr. Karreman is a graduate of the University of Pennsylvania School of Veterinary Medicine. Early in her career she moved to British Columbia, Canada where she spent twenty years working with the BC salmon farming industry as a clinical veterinarian and as a consultant on fish health projects to the private sector, provincial and federal governments. Most recently she spent three years in Ottawa with the Canadian Food Inspection Agency as the National Manager for Disease Control and Contingency Planning for aquatics. In June she returned to live and work in British Columbia. She is now the VP for Regulatory Affairs for Syndel Laboratories/Western Chemical Inc.

Potential disease risks and benefits on a cold water IMTA farm

Michael Pietrak, Sally Molloy, Deborah Bouchard and Ian Bricknell
Aquaculture Research Institute, University of Maine

In order to diversify farm production and to develop more environmentally sustainable finfish production systems, marine finfish producers in the Northeast are adapting an integrated multi-trophic aquaculture (IMTA) approach by growing mussels with marine finfish species. Shellfish play a critical role in an IMTA system by extracting particulate bound organic nutrients; however they may also influence pathogen dynamics by serving as a reservoir or as a barrier for important finfish pathogens, depending on pathogen physiologies. This project uses a mussel (*Mytilus edulis*) model to investigate the associated aquatic animal health benefits or risks associated with IMTA. Mussels are capable of removing both bacterial and viral finfish pathogens from the water column; however, the fate of those pathogens within the mussel differs. ISAV, an enveloped virus, is taken up by mussels and viable virus is nearly eliminated from the tissues within 24 h. We observed a continuous decrease in ISAV RNA in mussel digestive gland out to 6 days after exposure to 10^4 $TCID_{50}$ ml^{-1} of ISAV. However, viable ISAV was not detected in these tissues by $TCID_{50}$ analysis, suggesting that the mussel is removing ISAV particles from the water column and inactivating the viral particle. *Vibrio anguillarum,* however, remains viable and is quickly shed through the fecal and pseudo-fecal matter but not directly into the water column. Because *V. anguillarum* remains viable in mussel fecal matter for at least three weeks, marine sediments below mussel rafts and finfish cages may be a potential reservoir for *V. anguillarum.* The combined results of these studies highlight the importance of understanding how different pathogens interact with both mussels and fish on an IMTA farm. While mussels may reduce the infectious pressure for some pathogens, they may also increase the likelihood of disease transmission through alternative pathways.

Michael Pietrak has been involved with the aquaculture industry in Maine for the past 10 years. Since 2002 he has been the project manager for the Maine Aquaculture Association (MAA). His work at MAA has focused on applied research for the industry and public education. Research at the association has included development of a containment management system on salmon farms, development of various best management practices and techniques for composting hatchery wastes. More recently he has been involved in a collaboration among four East coast states looking at a fresh water IMTA system integrating aquatic plant culture into existing aquaculture operations. In 2008, Mike started working towards a PhD in Marine Biology at the University of Maine's Aquaculture Research Institute. His graduate studies are focused on the ecology of diseases on a mussel-finfish IMTA farm.

Aquaculture Chemical/Drug Use Concerns

Jack Word, PhD
Partner and Director of Environmental Sciences, NewFields Northwest, P.O Box 216, 4729 NE View Dr., Port Gamble, WA. 98364, 360-297-6060, 360-808-7705 cell

Integrated Multi Trophic Aquaculture Systems (IMTA) provides multiple food products under intense aquaculture. The use of chemicals or drugs is kept to a minimum but there are concerns and perceptions that culture of aquaculture species under open pen culture can lead to risks associated with the addition of chemicals, the removal of various nutrients that foster the aquaculture species at the risk of organisms that naturally occur in those environments, or that might be bioaccumulated into food tissues from natural or introduced sources of chemicals. The presentation will discuss these potential concerns and provide methods of monitoring that can be used to alleviate or minimize the perception of these issues that might arise under any intensive culturing of food products.

Jack Q Word is a Partner and Director of Environmental Research Programs at (NewFields Northwest) where he designed and built a state-of-the art biological testing facility located in Port Gamble, Washington. He is a fisheries scientist with over 40 years of experience and holds a Doctorate in Fisheries from the College of Oceans and Fishery Sciences, University of Washington. His applied research has been conducted at a number of research facilities, including the Southern California Coastal Water Research Project, University of Washington, EHI, and as a researcher, Director and Manager of the Battelle Marine Sciences Laboratory, MEC Analytical Systems and NewFields NW. His areas of study have covered a broad range of topics from the effects of organic enrichment and chemical toxicity on benthic communities throughout the west coast of the United States to extensive research on the development and testing of numerous species used in applied toxicity testing of sediment and waters ranging from standard sediment tests to special studies on the effects of contaminants on the early life *history of fish and invertebrates in areas including aquatic systems throughout the world. His wife and oldest son work with him at NewFields NW, while his daughter is a teacher in the north Seattle area and his youngest son is a nearing completion of training as a chiropractor.*

Species Selection

John Forster
Forster Consulting Inc., 533 East Park Avenue, Port Angeles, WA 98362, Phone 360 452 7917
jforster@olypen.com

Choice of species for IMTA projects depends on the scale at which production is contemplated. If marine aquaculture continues to be confined to near-shore locations, the likelihood of it being able contribute substantially to the 6-7 million mt of seafood per year consumed in the U.S. is limited even with IMTA. However, this means that there may be more species options because small production volumes can be sold in niche markets at high prices and farming conditions will be less demanding.
On a larger scale, IMTA is likely to have to be done in more open, 'offshore' waters and the difficulty of farming offshore together with pricing pressure on larger volumes may limit species choices. Clear definition of the species attributes required for large-scale offshore IMTA would be a valuable outcome from this workshop.
On a larger scale still where marine aquaculture might, one day, contribute substantially to global food supply, models from integrated agriculture suggest that farming should be based on plants as the primary source of biomass and nutrients. Further, they show that though integration is fundamental, as when farmed animals are fed with farmed plants, production is often partitioned rather than multi-trophic.

Forster has worked in the aquaculture industry as a scientist, manager, consultant and fish farm owner since 1965. Today, he serves public and private sector clients as an advisor on the aquaculture business. He moved from the UK to Port Angeles, WA in 1984 and helped Stolt Sea Farm to develop its West Coast salmon and sturgeon farming operations before starting his own business in 1994. In the same year, he founded Columbia River Fish Farms, a producer of steelhead trout. He has served on NOAA's Marine Fishery Advisory Committee and on the boards of several private aquaculture companies.

Biofloc Technology and Application to Intensive Production of Marine Shrimp

Dr. Doug Ernst
NaturalShrimp Corporation, 502 Robinhood PL, San Antonio, TX 78209, dernst@NaturalShrimp.com, www.NaturalShrimp.com, www.AquaFarm.com

Fundamental concepts of biofloc technology (BFT) applications for aquaculture systems are reviewed and a specific application of BFT to intensive production of marine shrimp is described. Components of biofloc include inorganic and organic particulate solids, heterotrophic and chemoautotrophic bacteria and fungi, photoautotrophic and heterotrophic algae, and micro-organisms including protozoa (amoebas and ciliates), nematodes, and zooplankton. In a context of integrated multi-trophic aquaculture (IMTA), the biofloc community and target crop of BFT systems represent a multi-trophic ecosystem including bacterial-detrital and photosynthetic food chains, filter deeding detritivores and herbivores, and predator-prey relationships. Formalized BFT started in the late 1970's and has been mainly applied to tilapia and marine shrimp systems.
Advantages of BFT follow from its two main features. First, biological water treatment in culture tanks reduces or eliminates needs for water exchange and/or treatment systems, with a corresponding reduction of water consumption and waste, improved environmental control and pathogen biosecurity, and simplification and cost reduction of facility design. Second, recycling of feed, fecal, and microbial solids as a food resource for cultured animals supports a substantial increase in food and nutrient conversion efficiency. Disadvantages of BFT include oxygen consumption of biofloc and energy

requirements for maintaining biofloc in suspension. Unique features of BFT system operation include maintenance of desired biofloc concentrations and ecology, management of biofloc carbon-nitrogen ratios based on ammonia dynamics, and control issues for harmful and beneficial bacteria.
At NaturalShrimp's facility near San Antonio, Texas, intensive BFT systems are used to produce Pacific white shrimp (*Penaeus vannamei*) on a continuous, year round basis in a closed system. Plastic-lined shrimp culture tanks in greenhouse ("light system") and insulated barn structures ("dark system") are equipped with automated feeding, hydronic heating, aeration, oxygenation, solid clarifiers and fractionators for biofloc removal, and denitrification reactors for nitrate removal. Brackish culture water is made from a public water supply and sea salt (temperature 30 C, salinity 15 ppt). Ammonia and nitrite are maintained by water-column bacterial nitrification and heterotrophic uptake. The biofloc carbon-nitrogen ratio is maintained in a desired range through the protein content of shrimp feeds and additional carbohydrate applications. A specialized blend of probiotic bacteria is applied via shrimp feed and directly to culture water for control harmful bacteria (*Vibrio* spp.). Use of marine macroalgae reactors to treat used culture water prior to reuse is under development.

Economic Perspectives on Integrated Multi-Trophic Aquaculture
Gunnar Knapp
Institute of Social and Economic Research, University of Alaska Anchorage, 3211 Providence Drive, Anchorage, Alaska 99508, Gunnar.Knapp@gmail.com, 907-786-7717

The future development of Integrated Multi-Trophic Aquaculture (IMTA) will depend on both how financially profitable it is for farmers and how it is regulated. From the perspective of farmers, IMTA offers a number of potential economic advantages in comparison with non-IMTA, including increased physical production from a given site, greater diversity of production, and more intensive use of facilities, labor and sites. These must be balanced against potential economics disadvantages such as greater complexity, more risks, and greater challenges in site selection.

From a public perspective, IMTA offers significant potential public benefits in comparison with non-IMTA, including reduced negative environmental impacts and positive ecosystem services. Although methodologies exist to estimate the economic value of these benefits, they can be expensive and imprecise. From a policy viewpoint what matters is not necessarily what economists estimate the value of these public benefits to be but rather how they influence regulators and the constituencies which influence regulators. In theory, we might expect the environmental benefits of IMTA to contribute to greater "political viability" and a more favorable regulatory environment. However, these environmental benefits will not necessarily defuse opposition from groups that object to aquaculture on non-environmental grounds, such as effects on vacation-home viewscapes or markets for wild fisheries, or philosophical objections to private use of marine waters.

The most effective way to advance IMTA is to design appropriate regulatory institutions which provide a stable enabling regulatory framework under which aquaculture can develop in a responsible way. Farmers will have greater incentives to adopt IMTA if regulatory institutions find ways to align the interests of fish farmers with those of society, so that farmers pay for environmental costs they impose on society and are paid for ecosystem services they provide. The development of IMTA will also depend critically on how effectively the aquaculture industry engages in research and innovation for IMTA technologies, marketing of new IMTA species and products, and participation in the political process to promote appropriate regulatory policies.

The true test of the potential of IMTA will be its ability to succeed commercially and politically. Successful industries are not created by "intelligent design": they evolve through competition in a highly competitive global economic system. We can best help that process by creating a regulatory system that allows and encourages those new technologies to evolve which most benefit society.

Gunnar Knapp is a Professor of Economics at the University of Alaska Anchorage Institute of Social and Economic Research, where he has been engaged in research on Alaska resource management and markets since receiving his Ph.D. in Economics from Yale University in 1981. In particular, Dr. Knapp has studied markets for Alaska salmon and other fish species and how they have been affected by competition from farmed salmon and other factors, and how the Alaska seafood industry has responded to changes in world seafood markets. Together with Professors Cathy Roheim and Jim Anderson of the University of Rhode Island, Dr. Knapp wrote the 2007 report "The Great Salmon Run: Competition Between Wild and Farmed Salmon" (www.iser.uaa.alaska.edu/iser/people/knapp). He also authored chapters on the economic potential for U.S. offshore aquaculture and the potential economic impacts of U.S. offshore aquaculture for the 2007 NMFS study Offshore Aquaculture in the United States: Economic Considerations, Implications & Opportunities (http://aquaculture.noaa.gov/news/econ.html).

Community Acceptance
Sebastian Belle

Sebastian Belle began his career as a commercial fisherman, working his way through university as a mate on offshore lobster boats. Currently, Mr. Belle is the Executive Director of the Maine Aquaculture Association, a private non-profit association representing Maine shellfish and finfish growers. Mr. Belle sits on the National Organics Standards Board Aquaculture Task Force, the Standards Oversight Committee of the Global Aquaculture Alliance and the Boards of Directors for the USDA Northeast Regional Aquaculture Center, the Maine Aquaculture Innovation Center, The Maine Tourism Association and the International Salmon Farmers Association. Prior to joining the Maine Aquaculture Association, Mr. Belle was the state aquaculture coordinator working for the Maine Department of Marine Resources and managed commercial salmon and tuna farms. In 1989 Mr. Belle was one of the first salmon farmers to begin growing shellfish on salmon sites in an effort to diversify the farms production and recycle nutrients. Mr. Belle holds degrees in fisheries biology and agricultural economics and has served as a technical consultant and manager on over twenty commercial aquaculture ventures in nine countries. Mr. Belle has authored numerous articles and several book chapters on the development and implementation of Best Management Practices and Risk Control Programs on commercial aquaculture operations. In addition to his role as the Maine Aquaculture Association's Executive Director, Mr. Belle is President of Econ-Aqua, a consulting firm specializing in aquaculture project design, operations management, financial due diligence and risk analysis and control.