White Paper

INTEGRATED MULTI-TROPHIC AQUACULTURE: A WORKSHOP

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The first US-based workshop on integrated multi-trophic aquaculture (IMTA), which was sponsored by the Pacific Aquaculture Caucus and Peninsula College in Port Angeles, Washington, attracted a range of scientific experts and researchers along with aquaculturists from around the country. In the context of this workshop, IMTA was defined as the rearing of a fed aquatic species—which could be a fish such as salmon, for example—in association with species that occupy other trophic levels, making use of the waste products of the fed organisms. Typically, this association involves species such as seaweeds or plants to assimilate dissolved nutrients, filter-feeders such as mollusks to use suspended organic materials, and deposit-feeders to use settleable solids. However, there are various approaches to achieving the basic goals of IMTA that span freshwater and marine aquaculture.

Both the participants and the intended audience of the workshop spanned the range of stakeholders in aquaculture. The two-day event focused on examining the opportunities afforded by IMTA, both in theory and in practice, to address many questions concerning aquaculture in the US.

The first day consisted of presentations, starting with the example of IMTA development in Canada coupled with a cosmopolitan overview of IMTA system modeling. Several presentations explored components of IMTA systems in detail, and a subsequent series reconstructed the overall system perspective by examining concerns across ecological and socioeconomic areas. The second day of the workshop was devoted to discussion in three breakout groups identified as ecological, economic, and social impacts of IMTA. A framework of "strengths-weaknesses-opportunities-threats" (SWOT) analysis was used for small group facilitation, and findings were recorded to be later assessed through a survey of a random sample of workshop participants.

Some of the conclusions upon which the participants concurred are as follows. IMTA could help to move the US toward becoming a major aquaculture producer in the world, because it might resolve some of the issues that seem to be limiting such progress. It is a new approach that may be more acceptable to the general public and to local communities. The use of IMTA could answer public environmental concerns, by providing environmental services to recycle nutrients and by isolating cultured species and their diseases, for example, from the natural environment when applied in closed systems. It is perceived to be a sustainable type of aquaculture, in part because IMTA can make use of alternative feeds rather than those made entirely from fish. Further, there would be economic advantages from the multiple products that can be sold in new market areas, including niche markets, and IMTA would open many opportunities for research, innovation, partnerships, and education.

Possible weaknesses of IMTA seem to center on its complexity at various levels, such as the difficulty in explaining the technical aspects to the public and to regulators; operational challenges; and extra costs for setup and maintenance.

Up to the present time, factors that appear to have hindered the expansion of US aquaculture are the public concern about coastal zone use for the production of food, rather than for other purposes, the lack of social acceptance of aquaculture, and the absence of a regulatory framework that would allow aquaculture, including IMTA, to develop in a responsible way.

The workshop provided a means of informing and inspiring the US aquaculture community of the gains made in IMTA in other countries. Previously, in April 2010, a workshop in Europe on advancing aquaculture as a sustainable sector had included a presentation on IMTA, with a positive outlook and conclusions.

This white paper was posted for public review on the National Oceanic and Atmospheric Administration's wesbsite for 6 weeks. Several comments were received that simply expressed approval, and one that was substantive (see Appendix IV). Several points were raised in the latter: (1) IMTA incorporates ecological concepts, such as that of *food webs*; (2) "aquaponics" could be listed among IMTA approaches; and (3) future IMTA workshops could address applicability of IMTA to widely different markets; development of management teams and strategies to ensure economic viability of the various components of an IMTA operation; and more detailed "nuts and bolts" of IMTA business and technology, among other topics.

Integrated Multi-Trophic Aquaculture Workshop

INTRODUCTION

The synergistic cultivation and rearing of plants and animals is an ancient practice and continues to be used for extensive food production in many parts of the world. However, the intensification of terrestrial and aquatic food production—the so-called green and blue revolution, respectively—has been characterized by a monocultural approach along with the partitioning of feed, fertilizer, and food production components. The recognition of significant and deleterious environmental effects of this intensive and industrialized food production approach has led to a more recent reexamination and application of traditional practices of integrating multiple trophic levels in terrestrial and aquatic systems. The difference, however, lies in the level of intensification. Whereas traditional approaches of integration were natural outcomes of extensive system development and efficient resource use, the recent applications are deliberate steps taken to use intensive food production systems not only with greater efficiency, but also with an aim to both mitigate negative environmental impacts and achieve social license to sustainably use public resources, such as marine environments.

The first US-based workshop on integrated multi-trophic aquaculture (IMTA),[1] which was sponsored by the Pacific Aquaculture Caucus and Peninsula College in Port Angeles, Washington, attracted a range of scientific experts and researchers along with aquaculturists from around the country. In the context of this workshop, IMTA was defined as the rearing of a fed aquatic species—which could be a fish such as salmon, for example—in association with species that occupy other trophic levels, making use of the waste products of the fed organisms Typically, this association involves species such as seaweeds or plants to assimilate dissolved nutrients, filter-feeders such as mollusks to use suspended organic materials, and deposit-feeders to use settleable solids. However, there are various approaches to achieving the basic goals of IMTA that span freshwater and marine aquaculture (Barrington, et al. 2009).

IMTA is an important aspect of a larger effort called the ecosystem approach to aquaculture (EAA) to make aquatic food production more sustainable. The EAA concept is defined as "a strategic approach to development and management of the sector aiming to integrate aquaculture within the wider ecosystem such that it promotes sustainability of interlinked social-ecological systems" (Soto, et al. 2008). Three principles of EAA were identified at a recent United Nations Food and Agriculture Organization (FAO) workshop (Soto, et al. 2008):

Principle 1- *Aquaculture development and management should take account of the full range of ecosystem functions and services, and should not threaten the sustained delivery of these to society*

Principle 2- *Aquaculture should improve human well-being and equity for all relevant stakeholders*

Principle 3- *Aquaculture should be developed in the context of other sectors, policies, and goals.*

These principles reflect the growing awareness that sustainable human development, including aquatic food production, requires recognition and action in not only the technological arena, but also in the wider ecosystem and in social arenas of human existence.

This IMTA workshop was inspired by three things. First, the organizers recognize the economic and food security benefits of increased aquatic food production in the United States (US). Although the country possesses significant resources that could be sustainably applied to aquatic food production, progress to increase domestic production and reduce the significant trade deficit in seafood has been slow. The National Oceanic and Atmospheric Administration (NOAA) has identified one of the challenges facing US aquaculture as the need to better understand the environmental and socioeconomic implications, and ecosystem carrying capacity for marine aquaculture (NOAA 2007). The workshop was intended to address this need by examining the opportunities afforded by IMTA, both in theory and in practice.

[1] "Integrated" refers to the synergistic system in which several different species play a role in the resulting increased production and reduced waste stream of the aquaculture endeavor, and "multi-trophic" describes the ecological roles of the various species involved such as photosynthetic production of algae and heterotrophic use of waste solids by filter feeding organisms.

Second, the pioneering efforts by aquaculturists in Canada and elsewhere to use IMTA for temperate aquaculture suggest that the US aquaculture industry could apply some of the same technologies. The workshop provided a means of informing and inspiring the US aquaculture community of the gains made in IMTA in other countries. Previously, in April 2010, a workshop in Europe on advancing aquaculture as a sustainable sector had included a single presentation on IMTA as a responsible practice (Thierry Chopin, University of New Brunswick, Canada, in OECD 2010). The chairman's executive meeting summary concluded that "[w]hile the technical feasibility of introducing IMTA on a larger scale has been proven in Asia, in many other parts of the world the rapid expansion of such systems is challenged by reasons of social acceptance" (OECD 2010).

Finally, the concept of a social license for all users of the environment could be of key importance to the aquaculture community in its endeavor to come to grips with the loss of invaluable terrestrial and marine coastal resources, both from rapidly increasing global population density in the coastal zone and from declining fisheries. The workshop framework guided participants to consider IMTA in the context of potential social, as well as economic and ecological impacts.

The participants and audience of the workshop spanned the range of stakeholders in aquaculture: producers, suppliers, representatives of advocacy groups, consumers of the products, and regulators. The basic design of the workshop was to deliver current findings through presentations, and then to provide breakout sessions to produce stakeholder-derived information that could inform the US aquaculture community.

The workshop was organized with the view of providing a comprehensive yet concise view of IMTA to serve as a foundation for discussion and for development of recommendations. The first day consisted of presentations, starting with the example of IMTA development in Canada coupled with a cosmopolitan overview of IMTA system modeling. Several presentations explored components of IMTA systems in detail, and a subsequent series reconstructed the overall system perspective by examining concerns across ecological and socioeconomic areas. The second day of the workshop was devoted to discussion in three breakout groups identified as ecological, economic, and social impacts of IMTA. A framework of "strengths-weaknesses-opportunities-threats" (SWOT) analysis was used for small group facilitation, and findings were recorded to be later assessed through a survey of a random sample of workshop participants. The following report summarizes the presentations, findings of the breakout sessions, and the analysis of the survey. This document should serve to further the national aquaculture goals of advancing scientific knowledge and heightening public knowledge of sustainable aquaculture.

A verbatim transcript of the workshop was taken and the meeting reduced to a précis of all the talks and commentary (Appendix I). In Appendix II are the author-supplied abstracts of the talks; Appendix III contains the extended SWOT analysis quantitative matrices. The PowerPoint presentations can be viewed through a link found on the Pacific Aquaculture Caucus website (Events).

PRESENTATION HIGHLIGHTS

Although they were separated by an ocean, a continent, and several time zones, the participants of the first integrated multi-trophic aquaculture workshop to be held in the US and their featured speaker were in synchrony when Portugal-based professor, Dr. Joao Ferreira, delivered his research findings to the group. "Significant enhancements occur both to production and environmental quality through the use of IMTA," Ferreira told the 60-plus participants. "These lessons need to be applied to the West."

Workshop speakers addressed a range of topics from the theoretical to the practical, and the presentations represented six major topic areas related to IMTA:

- ***Regional development*** was illustrated by the ongoing work of Canadian professor and aquaculture researcher, Stephen Cross, and the case study of his Sustainable Ecological Aquaculture (SEA) farm. Cross, who is the director of the Coastal Aquaculture Research and Training Network at the University of Victoria in British Columbia, offered an overview of the project launched 9 years ago in Kyuquot Sound, on the West Coast of Vancouver Island. His findings provided a practical example of the environmental and socio-economic challenges and benefits associated with commercial-scale IMTA. Cross is an innovator who is adapting and perfecting new equipment and farm configurations to advance his research and development.

- ***A conceptual framework*** was introduced by Joao Ferreira's highly-anticipated presentation, which highlighted the use of statistical modeling to better project and predict the environmental and economic benefits from an integrated aquaculture operation.
- ***IMTA components*** that were presented in detail included discussion of *finfish* as the engine for IMTA systems, because it is typically the major component that is fed and that generates the primary waste stream (Michael Rust); *feed inputs*, with emphasis on corn and soy, and fish-nutritional research (Steven Hart); *primary producers*, such as algae and kelp, which serve as extractors of inorganic materials out of the water (Doug Ernst); *filter feeders,* such as bivalve mollusks and certain fish, which are employed to extract contaminants and excess nutrients from aquaculture effluent (Peter Becker); and *deposit feeders*, such as sea cucumbers, which can take care of solids that would settle to the sea floor, or earthworms for a similar cleanup-role in combined aquatic- and land-based systems (Jack Ganzhorn).
- ***Concerns about IMTA*** included presentations on prevention of infectious diseases in finfish—that is, aquacultural "biosecurity" (Grace Karreman); the question of whether IMTA might decrease or possibly increase disease risk among cultured species, and a discussion of modeling and molecular techniques to identify pathogenic organisms (Michael Pietrak); the use of an antibiotic and other chemicals in aquaculture, and techniques for monitoring and modeling potential toxicity issues that could result (Jack Word); and the need for careful selection of species to use in IMTA systems, along with questions concerning the goals, mission, and potential for this type of aquaculture to contribute to the world's food needs (John Forester).
- Two ***IMTA case studies*** were presented: the *SEAVision Group* has a sablefish farm on Vancouver Island went through a long process of research, development, and innovation on the path to gaining a license in Canada to use shellfish, kelp, sea cucumbers, and urchins as components of an IMTA-type of commercial aquaculture production system, and which includes a sensitivity to First Nations concerns, alternative energy use, development of special equipment, and involvement in research, education, and training as part of its program (Steve Cross); and *NaturalShrimp,* a marine shrimp farm in Texas uses a biofloc system, involving a complex community of microorganisms to treat the shrimp-production wastes, which are put back into the food chain as a resource—the shrimp farm is essentially like a biotechnology company, using modern laboratory, communications, and modeling techniques in its operation in a completely closed, land-based facility (Doug Ernst).

IMTA socioeconomics filled the final spot in the day of presentations, and highlighted some of most important themes that emerged from the workshop. The *economics* of IMTA were discussed in the context that if this is a good approach, and if it can be shown to be profitable, the key to its success will be its political viability—that is, the social acceptance of IMTA as a form of aquaculture that society can "live with." As with any kind of aquaculture, for IMTA to succeed, it will be necessary to have in the US the appropriate political and regulatory institutions to provide a stable enabling regulatory framework under which aquaculture can develop in a responsible way (Gunnar Knapp). The topic of *social acceptance* of IMTA was elaborated in a presentation by the Sebastian Belle, executive director of the Maine Aquaculture Association, in which he described David vs. Goliath scenarios that play out over and over in Maine, as local fishermen and aquaculturists who apply for commercial aquaculture permits are met by cadres of lawyers representing waterfront landowners opposed to their business, because of the shift in the demographics in the coastal communities: fewer and fewer residents have traditional ties to the ocean, and accordingly have less tolerance of aquaculture and working waterfronts—rather, their interests are in recreation and tourism. Belle detailed the necessary attitudes, steps, and approaches that aquaculturist must learn to employ to earn the trust, and win—and then maintain—the acceptance and consent of the community to allow them to build and operate their IMTA or other aquacultural enterprises.

BREAKOUT SESSION HIGHLIGHTS

In Wednesday's breakout sessions, participants engaged in an in-depth process to evaluate potential impacts of IMTA using a planning tool by which strengths, weaknesses, opportunities, and threats (SWOT) can be assessed. SWOT analysis was created under Albert S Humphrey at Stanford Research Institute as a form of stakeholder analysis (TAM 2010). Identification of elements in these categories can sometimes be essential to a planning process: decision-makers can determine whether a goal or objective is attainable, in consideration of the SWOT results. If the objective is not seen as attainable as a result of this analysis, a different objective may be selected and the process repeated. SWOT analysis is particularly helpful in identifying areas for development. In a SWOT analysis of a company, for example, strengths and weaknesses are thought reflect the internal capabilities of the company, whereas the opportunities and threats originate outside the organization, but affect its operation (Nelsen and Scoble 2006). This type of analysis has been used in academia; it also can be applied by any group attempting to define and decide on how to achieve a common goal or objective. It can also help to manage and interpret large volumes of diverse, situational information (Nelsen and Scoble 2006).

Specifically for the IMTA workshop, the SWOT analysis was intended to help anticipate needs and concerns of stakeholders that must be met if this approach to aquaculture is to succeed. The participants of each breakout group at the workshop were self-selected, and some individuals visited more than one group during the sessions. In the three groups, which were focused respectively on ecological, economic, and social impacts of IMTA, participants collaborated to populate each of four quadrants of a SWOT analysis grid. Many of the factors appear in multiple quadrants—that is, a strength could be related to an opportunity, whereas a weakness could lead to a potential threat, for example, or in some cases, the same bullet could appear in all four quadrants. The resulting three SWOT grids for the three respective breakout sessions are shown in detail in Tables 1, 2, and 3, below. The factors listed within the quadrants were not directly quantified. However, in an extended analysis (summarized below), a method was used by which relative values could be assigned—that is, one can apply a semi-quantitative evaluation such as has been used in other studies "to measure [stakeholders'] beliefs, opinions, and perceptions (On Common Ground Consultants and Robert Boutilier 2010).

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SWOT ANALYSIS SURVEY

To extend the SWOT analysis, the importance of each element was quantified as follows. A random number generator was used to pick 15 registrants from the IMTA workshop to be asked to respond as "quantifiers" of the SWOT analysis. The three SWOT outcome grids were supplied to each one, with instructions to select the five most important elements in each quadrant, and to assign each a value based on a 1 to 5 scale, on which 5 was "most important." Each value, 1 through 5, could only be used once. If there were fewer than five elements in a quadrant, the respondent was directed nonetheless to use the same 1 to 5 scale. In every case, not all values were required to be used, and a choice of "none" was a valid option. Once the responses had been received, their numerical assignments were combined on a single SWOT quadrant for each of the three topics: the ecological, economic, and social matrices. The numerical assignments were summed for each of the SWOT factors, and the totals are shown in Appendix III (Table A-1), along with the detailed analysis thereof.

Eight of the randomly chosen participants responded. It was apparent from the IMTA data is that the basic principles of a SWOT analysis were understood by the quantifiers: that is, opportunities and strengths are conditions internal and inherent to the subject (i.e., IMTA) that should be evaluated in terms of how well, or whether indeed they might help to grow, evolve, develop or promote the concept. In contrast, weaknesses or threats are formed externally to the subject, may involve misapprehensions about the subject, and are not necessarily even strictly limited to the subject area—that is, for example, a threats valued highly in the Ecological Impacts area may have more to do with economic or social issues.

Table 1. IMTA Ecological Impacts SWOT Analysis

STRENGTHS	WEAKNESSES
• nutrient recycling (especially in closed systems) • reduced demand for feed from pelagic marine fisheries and terrestrial crops • greater emphasis on quantifying ecological effects • increased farm productivity • increased farm crop diversity • application to a variety of environments (e.g., land-based or marine-based), alleviating impacts on coastal zones when sited inland	• lack of thorough understanding of environmental impacts • currently emphasizes only high value products and thus less likely to contribute to world food needs (except seaweeds) • converts more resilient food webs to more vulnerable food chains • shifts nutrients flows in the environment to reduce natural production
OPPORTUNITIES	**THREATS**
• more data-driven decision making in aquaculture development • remediation of anthropogenic eutrophication • if IMTA increases domestic production, decreased environmental costs (e.g., transportation) of imported seafoods • aquaculture research platform • potentially greater profitability compared to existing aquaculture systems • produce products (such as seaweed-based biofuels) that would reduce environmental impacts of fossil fuels • specialized markets for IMTA products • grower collaboration	• larger scale applications may have greater environmental impact and thus less social license • potentially lower profitability compared with existing aquaculture systems (in the short term) • not enough public funding (i.e., political will) for developing a network of demonstration and research sites to examine the feasibility of IMTA

Table 2. IMTA Economic Impacts SWOT Analysis

STRENGTHS	WEAKNESSES
• efficiency: nutrient uses, coastal space • marketing advantages • new image: differentiated coastal aquaculture • diversified products = risk production • operational efficiencies: labor, operational rates, leasing • ecosystem services revenue opportunities	• complexity: marketing, operations, juveniles, business planning • risks: structural, disease, operations, seed supply • site-specific criteria (because of multiple species): salinity, current, temperature • greater capital costs for start-up • regulatory complexity
OPPORTUNITIES	**THREATS**
• markets: pricing, raise high-value product, packaging, niche opportunities • "sustainable" image • ecosystem services, potential revenue • development platform: new products, aquaculture innovations, feed, macroalgae, research • use IMTA as launching platform for national aquaculture vision • accelerated innovation potential • adaptability (e.g., climate change) • new partners	• social acceptance, public perception • natural threats: disease, parasites, storms • disappointment of expectations: failures could reflect badly on entire effort • market threats: overproduction, price cycles • competition from monoculture • cheap imitation of IMTA • greater regulatory requirements • new competing users

Table 3. IMTA Social Impacts SWOT Analysis

STRENGTHS	WEAKNESSES
• strong brand/green business • species diversification • opportunities for business (niche) • visual perception of aquaculture operations • educational opportunities • ecologically sound • healthful food (protein, Omega-3) • scalable operation • young industry—new model • commerce/jobs/living wages • rewarding enterprise • scientific discovery • preserve working waterfront • improve environmental condition • provide ecosystem services • year-round production, multiple species • lease revenues • good stewardship	• visual perception of aquaculture operations • fear of unknown • poor examples/failures could color overall perception • young industry • complexity • conflict of use (e.g., water, space) • lack of critical mass • capital intensity-scale • potential to downgrade monoculture • maybe greater privatization of public resources • economic viability • greater wildlife impacts and public perception thereof
OPPORTUNITIES	**THREATS**
• social awareness • local buying • niches • increase healthy food supply • initiate partnerships • education pathway • optimize nutrient loads • service industry jobs • eco-food tourism • regulatory design • control environment (marketability) • improve technology • opportunity to culture new ecologically responsible species	• competition in market • environmental degradation • shoreline development • user conflicts/space • financing • regulation or lack thereof • negative response to the label, "farm-raised" • uncontrolled messages (e.g., on the Internet) • misinformation • lack of marine spatial planning

The data seem to indicate the following trends (please see Appendix III for extended analysis):

1. **Ecological Impacts**: There was strong concurrence on five factors listed under this topic (that is, factors with value sums of mid-range or higher). In the area of strengths, the respondents agreed strongly on the importance of a benefit or service to the environment that could be provided by IMTA (*nutrient recycling especially in closed systems).* Strong concurrence on one weakness qualified the enthusiasm for the environmental service that had been seen as a strength, by pointing to the *lack of thorough understanding of environmental impacts* of IMTA. The threats upon which the respondent group agreed most strongly were not directly in the area of ecology, but rather expressed concern about the economic feasibility of IMTA, and the impact that environmental issues could have on the necessary social license to operate (*potentially lower profitability compared to existing aquaculture systems [in the short term]; not enough public funding [i.e., political will] for developing a network of demonstration and research sites to examine the feasibility of IMTA*; and *larger scale applications may have greater environmental impact and thus less social license).*

2. There was a high level of concurrence on seven **Economic Impacts** factors. The respondents agreed that the primary economic strength rests upon IMTA's *new image (differentiated coastal aquaculture*). Related to the value of that new image, they concurred strongly that the most important opportunities arise from the perception that IMTA offers sustainable aquaculture *(sustainable image).* The respondent group concurred that the weaknesses have to do most importantly with the complexity of IMTA (*complexity: marketing, operations, juveniles, business planning;* and *regulatory complexity)*, and that the economic threats would be lack of *social acceptance/public perception*; susceptibility to natural hazards *(disease, parasites, storms)*, and *greater regulatory requirements* for IMTA.

3. The factors under **Social Impacts** yielded the least concurrence, only on two factors in total—that is, the respondents saw the *complexity* of IMTA strongly as a weakness, as they had in the Economic Impacts section, and *misinformation* about IMTA as a strong threat. Therefore, although one of the major underlying interests of the meeting was to examine the concept of social license, which was addressed in several presentations and featured as the topic of the final talk of the day, the topic of social impacts may have been perceived as unresolved, with a wide dispersal of opinions or viewpoints among the diverse workshop-participant population.

CONCLUSION

Many of the items that showed higher concurrence were elements of concern about aquaculture in general. Although this workshop brought evidence through its presentations that IMTA may be a viable option to address many of these concerns to allow aquaculture in the US to progress, some uncertainty remains. It is clear that progress has been made elsewhere, in other countries. For example, ecosystem-based management of environments has been legislatively mandated in the European Union (EU) since its inception in 1990, and clarified in its policy statements (EU 2000). In EU coastal ecosystems, defined as the watersheds from the coastal range summits to the continental shelf-break, the mandate applies to activities such as agriculture and aquaculture within those boundaries. More recently, a European workshop in Paris, April 2010, reinforced those conclusions: in the chairman's report of the Organization for Economic Co-operation and Development (OECD) workshop in Paris on *Advancing the Aquaculture Agenda—Policies to Ensure a Sustainable Aquaculture Sector* (OECD 2010) at which Thierry Chopin made a presentation on IMTA, it was noted that the OECD group of countries produces 75% of the world aquaculture output outside of China and India. The report concluded that "[s]ustainable aquaculture should be ecologically efficient, environmentally acceptable, product-diversified, profitable and beneficial to society. Integrated multi-trophic aquaculture (IMTA) pursues these objectives [because it is a system in which] extractive species produce valuable biomass, while simultaneously rendering biomitigating services. This way, some of the externalities of fed monoculture are internalized, increasing the overall sustainability, profitability, and resilience of aquaculture farms."

The ecosystem-based approach of IMTA was evaluated at the present workshop for its potential to satisfy similar ecological, economic, and social concerns in the US and more broadly across North America. In the 15 major presentations, three collaborative breakout sessions, and finally in an extended SWOT analysis involving randomly selected workshop attendees, the participants concurred to a greater or lesser extent on several points, as follows, in consideration of some major questions put to the group by the presenters.

Why is the US not a major aquaculture producer on the world scene? (1) In the US, in contrast to China and some other parts of the world where aquaculture is intensively practiced, there seems to be major concern about coastal zone use for the production of food, rather than for other purposes; (2) there is a lack of social acceptance (political viability) of aquaculture; and (3) there is not a regulatory framework in place that allows aquaculture, including IMTA, to develop in a responsible way.

Is there indeed a role for the US as a major aquaculture producer, and will IMTA offer a special opportunity? Does IMTA supply that which will get society to accept aquaculture? Strengths of IMTA that could help move aquaculture forward appear to be that it is a new approach that could be more acceptable to the general public and to local communities because it can supply environmental services to clean up environmental contaminants where it is practiced in open systems, and can in closed, recirculation systems (which are self-cleaning, using techniques such as biofloc, for example) isolate cultured species and potential contaminants, diseases, etc., from the natural environment. There is a positive perception of the sustainability of IMTA systems, and of its ability to use alternative feeds rather than those made entirely from fish. Further, there would be economic advantages from the multiple products that can be sold in new market areas, including niche markets, and IMTA would open many opportunities for research, innovation, partnerships, and education.

Is IMTA a good idea? Strengths and opportunities are manifold. Concerns (weaknesses, threats) seem to center on IMTA's complexity at various levels—for example, conceptual, including the difficulty of explaining it to the public and to regulators; and operational, including extra costs for setup, construction, and maintenance; and regulatory, such as in policy, funding, and licensing issues. There is a concern that there is not adequate federal funding to expand current demonstration efforts, or to expand to new demonstration sites to carry research results forward into practical, commercial-scale application.

One of the major themes that emerged from this workshop was the need for, and current lack of "socio-political viability" of aquaculture—that is to say, a *social license* to operate. Even if aquaculture in the form of IMTA is technically, environmentally, and economically viable, it will not be successful in the US unless it is accepted by society in general, and by the local community and other stakeholders in particular, based on their beliefs, perceptions, and opinions. They must be convinced that IMTA has value and a positive role to play, and that the business is a part of the community, rather than an intruder or burden to it. This acceptance, if granted, encompasses not only *approval* of the aquaculture endeavor, but also the *consent* to allow it to be practiced in a particular setting. However, the social license is also ". . . dynamic and nonpermanent, because beliefs, opinions and perceptions are subject to change as new information is acquired. . . . Hence, the [social license] has to be earned and then maintained" (On Common Ground Consultants and Robert Boutilier 2010).

Finally, the workshop outcomes included a beneficial and positive interaction among stakeholders. Participants specifically noted the quality of the dialog throughout the meeting. Whether participants saw IMTA as a relatively new and promising approach for growing more seafood, or an effort to embrace a form of aquaculture already extensively used in Asia, interest in the concept was high. The workshop provided an open forum where new information was presented, and in which the participants discussed all viewpoints with an open and constructive attitude.

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Pacific Aquaculture Caucus (PacAqua)
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NOAA Aquaculture Program
Illinois Soybean Association, Indiana Soybean Alliance
Taylor Shellfish
Umami Sea Vegetables
SEAvision Black Cod
American Gold Seafood

LINKS

IMTA Workshop Pamphlet (on PacAqua website):
http://www.pacaqua.org/PacAqua_News/wp-content/uploads/2010/09/IMTA-Workshop-pamphlet-9-9.pdf

IMTA PowerPoint Presentations (on PacAqua website)
http://www.pacaqua.org/PacAqua_News/2010/09/integrated-multi-trophic-aquaculture-a-workshop-at-peninsula-college-port-angeles-washington/

OECD (Organisation for Economic Co-operation and Development) Workshop on Advancing the Aquaculture Agenda, Paris, 15-16 April 2010
http://www.oecd.org/document/3/0,3746,en_2649_33901_44041283_1_1_1_37401,00.html

APPENDIX I
IMTA WORKSHOP TRANSCRIPT PRÉCIS
Transcript and Précis by Susan A. Thomas

Tuesday, September 14, 2010

INTRODUCTION

Welcome
Tom Keegan, Peninsula College President, Port Angeles, Washington
Peninsula College wants to prepare students to live in a world of rapid change, to understand the environment, and to reach out to a diverse community. Further, the college wants to support and lead the economic development of its two-county area. For these reasons, aquaculture is an important area of interest, clearly because of its potential in economic development, and because it is a key breakthrough technology. We are pleased to host this conference because of our common goals and interests.

IMTA and US Aquaculture Policy
Kate Naughten, National Oceanic and Atmospheric Agency (NOAA), Washington, D.C.
NOAA looks forward to increasing its understanding of integrated multi-trophic aquaculture (IMTA), a promising technology, with its benefits and its viability to produce new seafoods. Along with other developing technologies, IMTA may be the key to the future domestic seafood supply. Emerging technologies include land-based closed recirculation systems and culture in exposed open-ocean waters. It is also necessary to see how some of these emerging technologies can complement and enhance existing coastal shellfish operations. NOAA's new draft national aquaculture policy will be released for public review in the next few months, and we look forward to your comments when the policy is released.

Introduction
Peter Becker, Pacific Aquaculture Caucus, IMTA Conference Organizer, Port Angeles, Washington
Today, the speakers will introduce aspects of IMTA and discuss potential impacts. Tonight there will be a dinner, the menu of which includes some IMTA-produced species and local wines, served in a pleasant atmosphere where you can talk together about what you will hear today. Tomorrow, there will be breakout sessions on the social, economic, and environmental impacts of IMTA. At the end of the meeting, we will produce a consensus white paper, to which you all will contribute by your participation in the workshop.

IMTA REGIONAL DEVELOPMENT

SEA System Development in Western Canada: Path from Research to Commercialization of IMTA
Steven Cross, University of Victoria and SEA Vision Group, British Columbia
On the Canadian West Coast, we conducted environmental impact studies and reviews of IMTA with attention to seafood safety, followed by field study of contaminant accumulation in shellfish placed as extractors downstream of salmon farms. Our results indicate that IMTA is a viable production model, but that there are some complex considerations, such as type of contaminants, potential interactions, the specific uptake by shellfish, and consequently, the need for careful selection of shellfish to employ in IMTA systems. Our scientific data provided a basis for regulation changes such that commercial-scale IMTA could be implemented in Canada. After 2005, we went beyond experimental stages to start commercial IMTA farming on Vancouver Island. We also joined a 5-year strategic research network funded by Canadian national agencies and involving researchers across Canada, different institutions, graduate students, and industry partners. A number of projects are underway as part of this program: Domain 1 is aimed at selecting species for use in IMTA; our Domain 2 consists of modeling many aspects and scenarios of IMTA operations on the East and West Coasts of Canada, and of engineering systems and special equipment for IMTA; the Domain 3 team studies economic and social impacts of IMTA.

IMTA CONCEPTUAL FRAMEWORK

IMTA Systems Modeling
Joao Ferreira, Institute of Marine Research, Portugal
We apply a multilayered ecosystem modeling approach as a tool for sustainable management in coastal zones. For example, we used our system-scale model, EcoWin2000, and others to study shellfish production under different polyculture scenarios in the Irish Sea, where the conflicting use of shore areas is an issue, as it is in Scotland, Portugal, and the US, as examples. In Asian countries, in contrast, coastal

zones are seen as places for food production. At Sanggou Bay, China, we applied system-scale modeling to examine circulation, key biogeochemical processes in IMTA, eutrophication with and without aquaculture. The best status of the system with respect to eutrophication was attained by the use of IMTA. System-scale and farm-scale modeling were used to analyze scenarios comparing oyster farming in monoculture vs. with fish-IMTA. Results were shown in terms of *people, planet, and profits*. The IMTA system has much higher profitability due to higher production, and because it removes detritus and phytoplankton via shellfish filtration, which leads to the net removal of nitrogen. The "population equivalent" of nitrogen removal is calculated in terms of quantifiable ecosystem service. One goal is to put a value on the benefit of nitrogen removal, so that the shellfish farmers can possibly become part of the nutrient credit trading system that is used in some US states and other parts of the world for improving water quality. It is a policy that can be used alongside regulation, but not in place of regulation, to let the market help to achieve water quality goals.

We are working with FAO to use an array of virtual tools to evaluate areas all over the world that have potential for offshore cultivation. The system-scale, carrying capacity assessment approach is a prerequisite for good management. Models exist to address local-scale components, environmental effects, etc., with profit optimization and aquaculture production. Significant enhancement occurs to production and environmental quality through the use of IMTA, because of the combination of species used at different trophic levels. We need to apply these lessons in the West, where we now run on monoculture.

COMPONENTS

Finfish

Mike Rust, NOAA Northwest Fisheries Science Center, Seattle, Washington

Why is the US not a major aquaculture producer? Is it because we view the value of coastal zones differently? Are we too concerned about the conflicting uses and values? Is there a role for the US as a major aquaculture producer, and will IMTA offer us a special opportunity? Fish culture provides the engine for IMTA via the waste streams it generates. If we want to have aquaculture, and at the same time maintain clean water standards with low impact to the natural environment and wild flora/fauna, we need a way to remove excess nutrients and wastes, and better still, to get a revenue stream from each phase of the setup. At Manchester station, we study the physiological characteristics of fish, their nutrition and wastes, and other variables that could make a difference in the output. Our results show that the species, size, and other characteristics of fish do make a difference, as does the fishes' diet, along with the way fish feed is processed. We focus on a recirculation system for fish-rearing using multi-trophic levels in a *closed* system on land, with revenue generated from every unit to offset the higher cost of construction and operation. In such contained systems, different species, such as exotic or perhaps even genetically modified fish/shellfish or other invertebrate species could be used, along with micro- and macroalgae, with perhaps more social acceptance due to a reduced chance for escape and mixing with native populations, and other potentially negative impacts to the natural marine environment.

Feed Inputs

Steve Hart, Indiana Soybean Alliance, Indianapolis, Indiana

The US is largest producer of soybeans, just under 90 million metric tons in 2008-2009. The US Soybean Checkoff Industry requires that half a percentage of income from the sale of soybeans goes into a program to advance soybean marketing, production technology, and the development of new uses, and that half of the money stays in-state. In planning for the sale of the projected increasing volume of soybean production over the next three decades, the Checkoff Board identified global aquaculture as one of the key target areas. In Indiana, we initially started our research with salmonids, which is a big industry that uses a lot of feed, then added marine shrimp, and now we're starting to address marine fish. We also focus on yellow perch, a locally popular species in the Great Lakes region. Our approach has been to look for research partners throughout the world, and to conduct university-level nutritional research, followed by work to optimize the amount of soy product that can be incorporated in feeds. The use of fish meal in fish feeds has been an issue, which we now can help to address by substituting soy and corn meal for at least some of the animal meal. *What happens when we change feed from animal protein to a plant-based protein, and what will be the effect of that down the food chain, considering the multi-trophic system of IMTA?* That's the kind of question we will have to answer if we're going to move forward.

Primary Producers
Doug Ernst, NaturalShrimp Corporation, San Antonio, Texas
To grow enough algae in *open systems* to offset the nutrients put out by a fish farm requires 4 to 12 m^2 of algae per square meter of fish. The algal product can be used for human or animal consumption, as a source of industrial hydrocolloids, or possibly of biomethane. In *closed systems*, algal bioreactors require an extra management step. In Canada, some closed systems are used for algae production for human consumption or for marine animal feed. At Manchester station in Washington, such a system treats the effluent from halibut culture. In a tumble culture with aeration for efficient culture of macroalgae, one can manage the water quality, light intensity, and algal density for maximum efficiency. Addition of fertilizer, trace metals, heated water, and UV sterilization to keep microalgae content down can help ensure production through the winter months. Modeling can help in system design. We use spreadsheet type models, and dynamic simulation models for analyzing business aspects, testing scenarios for stocking and management, and evaluating potential outcomes for growth rate and production.

Filter-feeders
Peter Becker, Olympic Aquafarms, Port Angeles, Washington
IMTA uses fish or shellfish filter-feeders to extract contaminants and excess nutrients from effluent, which is mostly fish or shellfish wastes, or land-based agricultural runoff. How filter-feeders interact with the environment, their uptake rate, and other aspects are available in the literature. Whether you select local species or exotics, you must consider local ecology, potential markets, and the need to engineer IMTA systems to accommodate them. Literature shows that 95% of particles coming from aquaculture systems, fish farms, and closed recirculation systems are ~20 microns diameter (5-200 micron range), and that they will settle. There is evidence that filter-feeders are selective in extracting particles from the water column, rejecting the rest. Thus, it is important to know the particle size of wastes from an IMTA system and to choose from among the wide range of bivalves and some finfish, the filter-feeders that will select the required particle size and type. Marketability of these secondary products is a factor, but it shouldn't be the overriding consideration. You could add a fish range alongside your primary fed fish to act as a first-stage biofilter and use a marine bivalve as the second stage. An example of an ecosystem-based IMTA model was built as a Peace Corps-style project in Malaysia in the 1990s to remove contaminants from shrimp farm wastewater, otherwise normally released into local waters. The project found that 72% of the nitrogen and 61% of the phosphorus could be removed, mostly as harvested shellfish product to be sold in the local marketplace, using a simple, engineered system. In general, the engineering considerations for IMTA systems can be calculated, and the engineered systems will probably be quite successful, because we can model them, and then create a business model that we can sell, rather than operating off an *ad hoc* system.

Deposit Feeders
Jack Ganzhorn, Peninsula College, Port Angeles, Washington
Often we grow fish at the tertiary level with food input. If we turn the model on its side and set it on top of the bar representing decomposers, detritivores, and scavengers as a food basis, we get a system based on a detrital pathway with allochthonous inputs, which is an important source of nutrients in natural systems. In a food production scheme based on this model, either humans or some of our target aquaculture species could use detritivores or microbivores as a food source. *What is the application to IMTA?* The criterion for species selection for IMTA use can be summarized as "efficient performance at a particular trophic level." Sea cucumbers, 23 species of which are commonly fished, fit the criterion for processing biosolids. Not typically consumed in the US, cucumbers bring a high price in Asian markets. Historically, they are grown in monoculture in ponds or by sea ranching. An Alaskan field study found them to be good at grazing and cleaning the net in small-mesh fish pens, and they grew better than did controls outside of nets, and thus could be a good antifouling organism. In other studies, they grew successfully in co-culture with mussels, and were ideal for polyculture in enclosed multi-trophic systems; they can be deployed in trays below oysters that are in suspended culture, or be buried in the sand below cultured shrimp. Other potentially useful detrivores are filter-feeding finfish such as mullet, or invertebrates such as crustaceans or annelid worms. Contained aquaculture systems could be operated in concert with worm composting, with terrestrial agriculture, and with biofloc technologies. At Peninsula College, we are finding good growth with worm meal from composting worms to feed the fish, which allows us to loop the waste stream back into the target species, thereby converting it to a revenue stream.

IMTA CONCERNS

Biosecurity Considerations (Finfish Disease)

Grace Karreman, Syndel Laboratories/Western Chemical, Inc., British Columbia

Three key things go into biosecurity measures for infectious disease: *bioexclusion,* prevention of pathogen entry; *within-site infectious disease control*, the management of pathogens within the facility; and *biocontainment,* the prevention of pathogen release. Risk assessment considers potential sources of disease introduction: waterborne pathogens; fomites. which are inanimate objects that can transfer pathogens; living vectors, meaning human visitors, divers, or other living organisms that might transfer pathogens as part of the life cycle; and feed. However, the manufactured feed on large salmon sites is not much of an issue. How can you set up barriers? Each site is unique. You can use physical/spatial barriers, distances between components with a site plan to separate them, fences between and around the parts of a site. A disinfection protocol can include footbaths, handwash stations, and requirements for changing clothes. To avoid contamination from fomites, disinfect equipment at sites; don't share between sites. In closed, recirculation systems, you can use vaccination as a tool. In IMTA systems, there are other potential sources of disease: the mollusks, crustaceans, invertebrates, algae, other marine plants--each could carry pathogen risk for salmon. It requires that you have expert advice in aquatic animal health and ecology. Mollusks can be both intermediate hosts for parasites and mechanical vectors that protect bacteria or viruses inside the shell. Salmon can be exposed to pathogens by mouth (oral route, through the gut), through the skin, wounds, abrasion, or, most likely, by waterborne pathways. In addition, sea lice, copepods, can harbor viruses such as *Vibrio*. These potential issues can be managed. Provide a good feeding regime so the fish aren't interested in miscellany in water. Use vaccines for gills, skin, and systemic protection. Decrease stress on the fish, manage their density. In summary, IMTA presents a more complex situation for biosecurity because you have to think about two systems that are interacting. It probably will call for more complex mitigation measures, but they are likely to be worthwhile.

Potential for Disease Transmission on an IMTA Farm: "Can I add another species?

Michael Pietrak, Aquaculture Research Institute, University of Maine

Does adding a species to an IMTA site increase disease risk on the farm, or might there be a potential benefit? Can we insert mussels in the route of a waterborne pathogen and intercept it before it gets to our finfish? If so, what is the complete interaction is between the mussel and the pathogen? Our approach is to use a transmission model, and realtime PCR for analysis. Based on experiments, we are fairly certain that for infectious salmon anemia virus (ISAV), mussels make a barrier, and we can use mussels as a highly preventative strategy to reduce the infection of ISAV on a site. It's not coming through the water as a pathogen if it's filtered by the mussels and it's not going through any sort of alternative pathways. With *Vibrio,* we did a similar experiment, putting the bacterial pathogen and mussels together in water. The mussels immediately took up bacteria out of the water, and very quickly bioconcentrated a 2 log order of viable bacteria in the tissues. A depuration study showed that subsequently, none of the bacteria was ejected into the water, but rather, only in the fecal and pseudofecal material. The literature suggests that *Vibrio* can live in sediment. We tested this by exposing fish to fecal matter from mussels and found that *Vibrio* can infect them after passage through the gut of a mussel. Another pathway of infection is via sediment. Even when we are careful in species selection and we engineer our sites deliberately, there can be unintended consequences that may or may not be able to be fixed. When you bring new animals onto the farm, you have new disease threats: completion of life history cycles of parasites, and a suite of indirect interactions. Although the fate of a pathogen in the system is going to depend on the physiology of the pathogen as well the species that you're growing on the site, in a larger view, these disease interactions are probably going to be relatively minimal, especially because we can apply good management techniques to minimize risk.

Aquaculture Chemical/Drug Use Concerns

Jack Word, Newfields, Port Gamble, Washington

Forty years ago, I heard similar talks about treating sewage effluent using different types of filter-feeding organisms and algae, as John Todd did in the '70s. The method is to create directed food chains: we change from the natural, unstructured food webs that have a lot of close interactions to others that are directed from one link to the next. They have the ability to build up concentrations of contaminants—chemicals, bacteria, or viruses—that would not necessarily be seen in an unstructured food web system. The *pros* of using

IMTA versus monoculture in an open container are that the products of one species are used to create value in the second, and as a result, there is decreased release of waste, plus you have early sentinels of environmental change around the aquaculture system. The *cons* are the potential to transfer contaminants from one part of the created food chain to another. It's not to the advantage of the aquaculture community to use many chemicals because of their cost. There are impacts to the surrounding natural community if antibiotics are released, and if certain nutrients are removed when they are taken up by the primary or secondary product. Toxicity can come from components added to the farm, and there's potential for local eutrophication, which we've heard a little about in terms of materials that might settle to the sea floor causing changes in the bottom communities. Aquatic vegetation also changes if there is more ammonia put into the system: dinoflagellates can bloom, and other algae can bloom rapidly as a consequence. There is a potential for cross-transfer of antibiotic resistance from one pathogen to another. Under IMTA, you have multiple species in culture, which could hold multiple forms of bacteria and viruses, which could show multiple resistance patterns. Modeling and monitoring in the field are important tools to predict, and then to validate the occurrence of changes. You can monitor water quality and sediment, you can inventory chemicals used at the site, also residuals outside the site (background), and monitor the accumulation in the farmed organisms, also look at its histopathology, body burdens, and taste. [*Note from Peter, there is only one antibiotic routinely used in aquaculture: oxytetracycline, with strict regulation and control.]*

Species Selection
John Forster, Forster Consulting, Inc, Port Angeles, Washington
What is our long term vision for marine aquaculture? What's our plan for 20 or 30 years from now? What are we trying to accomplish and what by then may be possible, technically? On what scale will be it done and where? And then when it gets to IMTA, *what will be the nutrient source that actually drives the process in the end?* It seems to me that species selection options might vary depending on some of the answers to those questions. We've already seen Sanggou Bay in China, and it's a good illustration—it is what serious IMTA on the coast means in terms of food production. In North America, we may not be too relaxed about using as much of our coastal space for aquaculture. NOAA says that we import about 80% of our seafood and that we eat 6 or 7 million metric tons of it. Therefore, one has to ask whether we're trying to address the question that Kate posed in terms of defining our mission—that is, whether we are trying to substitute some of the imports we get, or to feed ourselves, or to achieve seafood security in the future by using IMTA on a larger scale. For the discussions tomorrow, a workshop assignment could be to suggest some key criteria for species selection in IMTA, both on a smaller scale and on a larger scale. In current worldwide marine aquaculture (2007) only 10 species make up 63% of the total production, like chickens, pigs, and cows do in agriculture, and they are all grown widely outside their native range. Is that an issue? The problems of feeding the world in 2050 were considered at a recent FAO meeting in Rome. Is that part of our vision? A recent FAO book documents some food security issues and explores whether the ocean could be a potential large-scale food source for us all. We already produce products from seaweeds, as was discussed earlier today. However, we in the West know very little about using macroalgae as a nutrient and a feed source, as the Japanese do with their red seaweed *Porphyra*. There's a tremendous opportunity to take marine macroalgae and to try to process it as we do soybeans or other terrestrial crops, to create products of value. Our future might be in making marine plants feed the animals we grow in aquaculture what one might call a self-sustaining system, as are terrestrial agriculture/livestock systems that are driven by terrestrial plants at their base My final question is, *if we constructed a vision of marine aquaculture, where it might go, decade from now, based around that sort of model? Might that provide direction to some of the research that needs to be put in place right now, and might that also appeal to a wider constituency than seems to be the case in IMTA marine aquaculture in the US today?*

CASE STUDIES

Sustainable Ecological Aquaculture (in salt water)
Steve Cross, SEA Vision Group, British Columbia
The approach of sustainable ecological aquaculture (SEA) is to use the principals of ecology. Sustainability is viewed in the context of social, environmental, and economic factors and the ability to satisfy the needs of the present without compromising future generations, and in consideration of First Nations values. Our system is based on the IMTA plan, but also addresses other issues. Our earlier seafood safety research influenced the Canadian Shellfish Sanitation Program to lift its ban against growing shellfish within 125 m of a fish farm. In our remote coastal location, we integrate energy alternatives to reduce our carbon

footprint. I created and submitted my own management plan, and in 2006 received the first multispecies license in BC to grow 11 species commercially, although our model uses only 6 at a time. Only the sablefish is a fed component. Our organic subtractive filtration component is blue and gallo mussels, Pacific oysters, Japanese scallops, and the native cockle. Two tiers of shellfish, 15 m wide, 20 m deep, and 200 m long, are placed up against the fish to create an effective downstream filtration capacity. Any dissolved components that go through the filtration side are intercepted by an inorganic extractive component, *Porphyra* and *Saccharina*. Urchins and sea cucumbers serve as the deposit-feeding component; the latter are deployed in an engineered tray system beneath the fish, or may be thrown onto the seafloor (we have a license to release 30,000 cucumbers to the wild). We did one full year of research on sea cucumbers directly below the cage system. There will likely be a 35% to 60% increase in farm-gate revenue from the farm beyond that of the fish as a result of the extractive species. We had to be among the first to do a fish health management plan, as a condition of licensing. It is a dynamic document that we routinely upgrade for the site; it's a controlled document, designed like the International Organization for Standardization (ISO) program, covering procedures, best management practices, biosecurity for fish health, handling, procedures for visitors and for staff movements among components. The system innovations are still precommercial; we developed special equipment and infrastructure components, and are trying to incorporate wind and solar energy sources. We plan for expansion of our production sites, development of a floating hatchery, and an IMTA-branded product.

Biofloc (not only in brackish water)
Doug Ernst, NaturalShrimp, San Antonio, Texas
Biofloc technology can be applied in any salinity. Our company grows marine shrimp, *Panaeus vannamei,* using a biofloc system to treat the wastes, which are put back into the food chain to turn waste to resource. The advantages are increased conversions, reduced water consumption, waste reduction, and bioexchange. It simplifies facility design and improves biosecurity. Disadvantages are the conditioning time and the consumption of oxygen by the biofloc. Components of biofloc are bacteria, detrital aggregates, fungi, pelagic diatoms, green algae, and the facultative heterotrophs, filamentous bluegreen algae. A biofloc particle should be from 100 microns to 1 mm in diameter. This food web starts with filter-feeding fish or shrimp that produce fecal material. Part of the particulate organic carbon and nitrogen goes to the heterotrophs, which either excrete or take up ammonia. With a high carbon/nitrogen ratio, bacteria transfer the nitrogen to bacterial biomass. Denitrifying bacteria process ammonia to nitrite and nitrate; the balance is managed by maintaining the high carbon/nitrogen ratio and by controlling light intensity, feed input, and a biofloc cropping schedule. Issues are possible fouling by filamentous bacteria and outbreak of *Vibrio* that can quickly decimate the shrimp. We monitor *Vibrio* using total bacterial counts, and PCR for identification of strains; the probiotics used against *Vibrio* have antibacterial compounds and can disrupt *Vibrio* communication. NaturalShrimp is currently running as a saline system of 10-15 ppt, using both light (greenhouse) and dark systems (superinsulated barn) at 86ºF year-round in closed, clean systems for biological security. We stock and harvest biweekly to supply heads-on fresh shrimp to the adjacent metropolitan area. We buy 10-day post-larvae, manage the middle grow-out, and harvest at the size of about 20 per pound. Biofloc nutrient cycling activity takes place in the shrimp rearing unit, where shrimp are spread three-dimensionally in the water column via tiered structures. There is an aerated biofloc tank, and I'm developing combination clarifier-denitrification reactors. Although we are located in the middle of an agricultural zone, surrounded by corn on which pesticides are used, our air system is safe, with a completely sealed airspace and with supplemental oxygenation on top of aeration, and 100% humidity over the water. This water is 3 years old; there is zero effluent. Automated panels control heating, and all system information goes into a PC that interfaces with the Internet. Eventually, a manager will be able to watch over the system from a remote location. It's not a farm any more, it is more of a biotechnology company.

IMTA SOCIOECONOMICS

IMTA Socioeconomics
Is IMTA a good idea? Is it a "better" way to do aquaculture? What are the pros and cons of IMTA versus non-IMTA? The answers to such questions depend in great part on what we assume about our objectives for aquaculture—objectives such as profitability, efficiency, sustainability, not harming the environment, job-creation, equitability in benefit-flow, local control, food safety, local food production, and preservation of traditional values. They also depend on who responds: fish-farmers may be most concerned with profitability, non-fish-farmers with environmental impacts. Consumers may want lower prices, whereas

wild-catch fishermen do not want their prices undermined by aquaculture. Economists generally think our objectives should include economic efficiency and net benefits to society. Therefore, it will likely be difficult to achieve consensus on pros and cons of aquaculture in general and IMTA in particular.

Will the political economic system allow IMTA to develop, and if so, how? Does IMTA address the concerns people have about aquaculture, so that it will be more acceptable? For aquaculture of any kind to develop, it has to be both profitable and politically viable—that is, if society doesn't allow it, or doesn't allow it under conditions in which it can be profitable, it won't happen. The term *politically viable* is equivalent to what Mike Rust called the *social license*. The absence of a social license is holding back all aquaculture in much of the US and other places. IMTA ought to have advantages in overcoming that problem, because it can provide ecosystem services. However, IMTA doesn't address all the potential objections people express about aquaculture. For example, some people think that farming fish is just wrong, period. Some object to the aspects of aquaculture that may be necessary for its success, such as the involvement of corporations, industrial-scale production, use of technology, use of public waters, or the idea of growing food (at least *fish*) for profit.

What will affect whether or how it develops, and what should or can we do to advance it? We need to design of appropriate political and regulatory institutions that provide a stable enabling regulatory framework under which aquaculture, including IMTA, can develop in a responsible way. I think that's the fundamental thing missing in the US. These institutions must be capable of balancing and considering the interests of all stakeholder groups, not be captive to any group in particular, and be interested in balancing costs, potential problems, and benefits. For IMTA to succeed, we have to build mechanisms into the economic system that allow the interests of fish-farmers to align with those of society. We also need to find way to charge for or otherwise discourage costs that aquaculture inflicts on the environment, as well as to pay for or otherwise encourage ecosystem services it provides. IMTA seems to be an appealing, exciting technology with potential opportunity, but we should keep a healthy skepticism about it. We should support technological development through basic and applied research, pilot and demonstration projects, technology exchanges, and extension support. A critical factor for the success of IMTA is going to be how effectively the industry works for it, and in particular how hard the visionaries work for it—because they are the ones who believe in it and are best able to make it happen.

Community Acceptance

Sebastian Belle, Maine Aquaculture Association, Maine

In Maine, we have 135 to150 fish-farmers who grow actually 15, but basically 5 different species of finfish and shellfish. We have had lease sites in Maine since the industry began that are licensed for multiple species. Part of the application process for the series of permits and licenses needed to operate in the marine environment is an exhaustive series of meetings with the general public and all stakeholders. Now we're getting new licenses, new lease sites, and finfish sites without IMTA *per se*. We've learned some hard lessons. It's important to know that part of the constituency will not like what you do, whatever you do. Since the 1990s, a demographic shift to a population-base of retirees from other states (*away)* resulted, as summer-home visitors to our beautiful coast became year-round residents, changing the way that working waterfronts fit into the community. We have become essentially a one-fishery state: *lobster*. There used to be hundreds or thousands of ground fish permits; now there less than one hundred in the state and only two east of Ellsworth.. Maine currently leases 1300 acres from which we produce $120 million a year in product value, the two most valuable agricultural "crops" in the state, salmon and oysters. Coastal communities now view the ocean for "recreational use," and commercial fishermen and aquaculturists must make their case locally to people who have no history or link with the ocean for making a living. Over the last 20 years, we've learned that it takes basic common sense, hard work, and a lot of time to win the social license to operate. The reality is a battle between working people and people who don't have to work for a living: a social conflict.

Here is the short-course. *Acceptance 101*: You'll never get 100% acceptance, but if you can get locals to feel that it is "their" neighborhood farm, by sharing holiday seafood, becoming a part of their lives, helping them to be familiar with operations, they can change their attitudes. It doesn't happen with outside lawyers or environmental groups who come to town for their own agenda, with no vested interest in finding solutions. We talk directly to the people who are local and close to us, and avoid gatekeepers and external stakeholders. All politics are local, but local politics aren't always local. You're only as good as your last failure, so admit your mistakes and learn from them. *Acceptance 102:* Get to know the community and your audience, and talk to them. Don't talk to yourself. The best thing is to be good at listening to people. All concerns are legitimate by definition. Listen to every one of them, respond to every one of them. Always follow through. Never mislead or be evasive. Be polite. Avoid being defensive. *Acceptance 103:* The two levels of acceptance are legal and community. Form strategic partnerships. Communicate, use visual aids, show what a farm looks like to dispel fear of the unknown. Do your homework: find out what to do to make the community, the locals, comfortable with aquaculture.

Wednesday, September 15, 2010

IMTA SUMMARY OF BREAKOUT GROUP RESULTS

Jack Ganzhorn, ***Ecological Impacts***: It is a little artificial to partition the three aspects; we did end up talking about some of the social values under our decisions with respect to the environment. There was discussion of environmental change, both specific to the IMTA approach and to aquaculture in general, recognizing some of the diversity in terms of social values relative to aquaculture and the environment. Notable was the preponderance of opportunities and threats, as opposed to strengths and weaknesses in our lists, perhaps because of the degree of uncertainty. That is, when we think about strengths and weaknesses, we are thinking about things we feel more definite about, whereas opportunities and threats are probabilities. One of the key opportunities was the thought of being able to move forward in terms of production of aquatic foods as well as using demonstration and research facilities to develop IMTA. Finally, I was impressed by how open the presentations were in terms of strengths and weaknesses, and that was a good foundation to the conversation that we had today. It is a very positive sign in terms of moving forward in terms of aquatic food production.

Gunnar Knapp, *Economic Impacts:* *Strengths* of IMTA include its potential for efficiency in many ways, for example nutrient uses, coastal space, potential marketing value, because you are doing things in a way that is appealing. It has a new image: differentiated coastal aquaculture, diversification, providing ecosystem services. There are operational efficiencies in terms of labor, platforms, and sites. Significant economic *weaknesses* are the greater complexity of an IMTA over a monoculture system in areas ranging from operations to marketing to business planning to developing and managing labor. Complexity brings a variety of risks, such as damage to structures, disease, seed supply, etc. The criteria for site selection are more complex to balance needs of different kinds of organisms. Other weaknesses are higher startup capital costs and more regulatory complexity, because one must ask permission to do multiple things. *Opportunities* are in the markets, where there is potential for high-value products to enter niche markets, and in the fact that there is a favorable, sustainable image associated with IMTA. A potential long-term opportunity is revenue from providing ecosystem services; another is the opportunity for research— there is accelerated innovation potential, because it is new. There could be revenue from research, such as the intellectual property of new, potentially patentable techniques. We speculated on greater opportunities for adaptability to changes, such as climate change, with IMTA. There is opportunity for new partners, such as the grain and soybean industry, that are interested in supporting aquaculture as a wave of the future. We discussed the vision of where aquaculture ought to be decades from now. Some of us felt that IMTA is the only vision that makes sense: it is what aquaculture has to evolve to in order to become a major, significant producer on the global scale. Some of the opportunities are also potential *threats*: IMTA could enjoy greater social acceptance, but there is risk of disappointment if it does not meet expectations: any failure could be considered overall failure. Other threats include new diseases, parasites, storms, and overproduction causing market prices to fall, and the general problem of competing for with potentially lower-cost monoculture. There may also be a threat from "cheap imitation" IMTA—aquaculture with a little bit of nutrient recycling for show, but not really in the spirit of IMTA, degrading both the reality and the image. There's a threat of changing regulatory requirements, and of new competing users of the coastal area resources. For example, you might start your farm, and then retirees might move in and decide that they would like it better if farms like yours didn't exist. (*Group comment: maybe there needs to be some standard by which IMTA is defined, a minimum standard or definition*.) Yes, we discussed the idea of IMTA certification, but there is also a concern that that could lead to an [unreasonable] expectation that for aquaculture to be good or correct it has to be IMTA. Then what is IMTA, or how much is IMTA worth, when are you really doing it, what does that mean and who gets to claim that? (*Group comment: I would* *not want to see the expectation that IMTA is the only way for aquaculture to be in the future. The idea of IMTA of nutrient recycling is the important concept that needs to be at the forefront for aquaculture in the future, but there's other ways to accomplish nutrient recycling other than IMTA. I think we need to keep the idea of nutrient recycling as the main principle for aquaculture growth.*)

Gregg Bonicker, ***Social Impacts:*** Our group was diverse; we had producers, nongovernment organizations, consumers, other resource users, landowners, federal and state regulatory people—so we had within our group essentially all the key stakeholders for which social impacts could be determined. We found that we had to consider aquaculture in general and IMTA as a subset. IMTA's principal *strength* is that it provides a positive aquaculture story. Aquaculture was going to be "the Blue Wave" that could feed people, which faded out with commercialization, consolidation, and so forth; IMTA provides an opportunity for reframing the aquaculture story. IMTA could become a brand distinguished from other aquaculture as more of a green business. Part of the story is that it is healthy food, it is scalable, ecologically sound. Other strengths are diversification, niche marketing of the nontraditional secondary and tertiary crops. It's a new model, a young industry; there's the potential for scientific discovery and working with the regulatory agencies right from the beginning. *Weaknesses* are not necessarily specific to IMTA. The visual perception is an aquaculture issue, maybe exacerbated in IMTA because it can take up more area. The complexity of the IMTA concept can work against us, if the audience cannot understand the story. There is a lack of critical mass because it is new. There could be a potential to downgrade monoculture, if IMTA were perceived as better or more correct. Another weakness is economic viability and the public perception of that based on media coverage of any failure. *Opportunities* are to increase social awareness, understanding where food comes from, and the extra effort that is being employed by IMTA to fully use the nutrients that are going into the system. Other opportunities are to increase the healthy food supply, form interesting partnerships and educational pathways, and create service industry because of the specialized nature of some of the IMTA rearing situations, "ecofood tourism," regulatory design. Some of the *threats* are competition in the marketplace, environmental degradation, shoreline development, user-conflicts for space, difficulty of getting financing for an atypical type of aquaculture. Getting appropriate regulations in place will be both an opportunity and a threat. Because IMTA is complicated, we have a potential of seeing uncontrolled messages to the public that could be manipulated to work against us. Similarly, there is potential for misinformation. Another threat is the lack of marine spatial planning. It's always on a site-by-site basis, there are no "aquaculture parks" where there could be potential cooperation in onshore, nearshore, and offshore settings. *Group comments: (1) IMTA is not actually a new method, it is an evolution of our existing growing method. Maybe we should think of IMTA as "Aquaculture 2.0" where monoculture is "Aquaculture 1.0," and recognize that some people will start at level 2 instead of 1; (2) The NOAA presentation expressed a need for an ecological approach to aquaculture, which it seems IMTA could provide. From a conservation perspective, the extent to which data emerge to help inform decisions and bring some facts to bear is a good thing.*

Concluding Remarks: **Peter Becker**—Over the last couple of days here, we saw a sort of *integrated multi-trophic audience* who got together and talked over issues openly and without any rancor. These have been some of the best discussions we've had for many years. I was very pleased to see that we could bring this group together and attain this level of open discussion; it was even more positive than I expected. We also achieved a "first" in having Joao Ferreira coming to a scientific meeting without actually having to be here. I hope we can see more of that kind of technology used at future meetings. **Jack Ganzhorn**—A few months ago, Peter asked me about holding the conference at the college, and it fit perfectly with my sabbatical study with a focus on responsible aquaculture methods. I felt very comfortable, as did the college because of this strategic priority that the president mentioned yesterday. I especially want to thank Pete for instigating it, and for being very persistent. He was the mover. Thanks for coming to the college for this workshop and we look forward to continuing the collaboration. **Peter**—Jack is the one who made all the "tweeks" to make it work. I had the big picture, but when it came down to details, he made it happen.

APPENDIX II
ABSTRACTS (CONTRIBUTED BY THE AUTHORS)

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

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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 SEAvision 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
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[abstract not contributed by the author] We apply a multilayered ecosystem modeling approach as a tool for sustainable management in coastal zones. For example, we used our system-scale model, EcoWin2000, and others to study shellfish production under different polyculture scenarios in the Irish Sea, where the conflicting use of shore areas is an issue, as it is in Scotland, Portugal, and the US, as examples. In Asian countries, in contrast, coastal zones are seen as places for food production. At Sanggou Bay, China, we applied system-scale modeling to examine circulation, key biogeochemical processes in IMTA, eutrophication with and without aquaculture. The best status of the system with respect to eutrophication was attained by the use of IMTA. System-scale and farm-scale modeling were used to analyze scenarios comparing oyster farming in monoculture vs. with fish-IMTA. Results were shown in terms of *people, planet, and profits*. The IMTA system has much higher profitability due to higher production, and because it removes detritus and phytoplankton via shellfish filtration, which leads to the net removal of nitrogen. The “population equivalent” of nitrogen removal is calculated in terms of quantifiable ecosystem service.

One goal is to put a value on the benefit of nitrogen removal, so that the shellfish farmers can possibly become part of the nutrient credit trading system that is used in some US states and other parts of the world for improving water quality. It is a policy that can be used alongside regulation, but not in place of regulation, to let the market help to achieve water quality goals.

We are working with FAO to use an array of virtual tools to evaluate areas all over the world that have potential for offshore cultivation. The system-scale, carrying capacity assessment approach is a prerequisite for good management. Models exist to address local-scale components, environmental effects, etc., with profit optimization and aquaculture production. Significant enhancement occurs to production and environmental quality through the use of IMTA, because of the combination of species used at different trophic levels. We need to apply these lessons in the West, where we now run on monoculture.

Dr. 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
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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.

Dr. Michael Rust has worked in fisheries and aquaculture since 1980 both in developing countries, such as the Philippines and Haiti, and in developed countries, such as Norway, Canada and the United States. He has degrees from the University of Colorado (environmental biology - B.S.), University of California, Davis (animal science - M.S. and international agricultural development - M.S.) and the University of Washington (fisheries - Ph.D.). His research areas include aquaculture engineering and project development, fish developmental physiology and fish nutrition. Currently, as part of the ongoing NOAA-USDA Alternative Feeds Initiative, Dr. Rust along with his colleagues at the science center is pioneering alternative aquaculture feed ingredients from fish processing trimmings, soy, and other ingredients. The group is also collaborating with USDA on alternative feed formulations, larval nutrition, and feed efficiency.

Feed Inputs for Aquaculture: Soybean Industry's Perspective

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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

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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©).

Dr. 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. Dr. Ernst'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. He received his doctorate from Oregon State University.*

IMTA Components: Filter Feeders
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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 (i.e., 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.

Dr. 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
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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, their 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 Ganzhorn has taught the fisheries and aquaculture program at Peninsula College since 1990. His teaching responsibilities include courses in fish biology, fisheries ecology and aquaculture. Currently, he is conducting a sabbatical study of sustainable aquaculture practices which involves curriculum development and project collaboration. Mr. Ganzhorn 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
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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 analyze 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 104 TCID50 ml-1 of ISAV. However, viable ISAV was not detected in these tissues by TCID50 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, Mr. Pietrak started working towards a Ph.D. 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
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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.

Dr. 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

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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.

Dr. John 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

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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.

Dr. 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. Dr. Ernst'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. Dr. Ernst received his doctorate from Oregon State University.*

Economic Perspectives on Integrated Multi-Trophic Aquaculture

Gunnar Knapp
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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.

Dr. 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
Maine Aquaculture Association

Aquaculture facilities in public waters typically need a number of licenses and approvals in order to operate. The process of applying for and receiving these approvals often involves input from the general public and public management agencies. The process whereby aquaculture applicants seek and ultimately achieve community acceptance is discussed. Central to the successful achievement of acceptance is understanding community participants concerns and responding to them. Community concerns must be actively sought out. Acceptance that all concerns, no matter how seemingly trivial, are legitimate and must be responded to is discussed. How communities are defined significantly impacts the nature and extent of the response necessary. A number of methods for building project acceptance including, community outreach, strategic alliances, effective communication and dealing with extremists are discussed.

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

APPENDIX III
EXTENDED SWOT ANALYSIS: MATRICES AND GRAPHS

*The following discussion refers to the results of the IMTA Workshop breakout sessions, in which three groups addressed, respectively, the ecological, economic, and social impacts of IMTA, and listed the potential issues in categories of strengths, weaknesses, opportunities, threats, and to the SWOT Analysis Survey that extended the analysis by asking 15 randomly selected workshop participants to rank the importance of listed issues using a scale of 1-5 (see pp. 7-9); 8 responded. The numerical assignments made by the respondents are summed in **Table A-1** and shown graphically in **Figures 1-12.***

Analytical method

The 1-to-5 scale was based on attempts by several other groups (e.g., World Wildlife Fund's Species Dialogs) to determine consensus based on the determination that "80% of the significant issues could be defined by 5 elements." Social scientists experienced in surveying and gathering social data on attitudes on aquaculture confirmed that this is a valid approach (N. Mazur, 2011, personal communication).[1] Other studies have employed different scales, such as in Sheppard (2008),[2] in which a 1-to-10 scale was applied that translates values from *slightly, moderately*, and *substantially important* into numerical values. These values are then averaged them and placed on a four-by-four matrix on which the principle vector (*eigenvector)* can be calculated relative to each factor; the resulting eigenvector represents the relative importance to all of the participants, collectively. Sheppard warned that factors derived from a SWOT analyses, although a valuable situational analysis tool, could be seen as arbitrary and capricious. Thus, there is always a risk of overanalyzing social sciences data.

The question of validity of the analysis arises with both the value-scale selected, and with a small sample size of respondents. It seemed clear from the responses that the instructions for assigning values on a particular scale were clearly understood by those who responded as quantifiers; however, there were only 8 of the 15 randomly chosen participants who responded in time for consideration in the present white paper, representing approximately 13% of the total number of workshop attendees.

With this sample size of N=8 respondents, there is only one case in which consensus is certain: if all respondents assigned the value 5, to a factor, the sum-value for that factor would be 5 x 8 = **40**. However, there are other reference values of potential interest. If all respondents assigned the value 3 to a factor, which is the midpoint between 1 and 5, the resulting sum would be 3 x 8 = **24.** Therefore, any combination that yielded a sum total of 24 could possibly be interpreted as a mid-range valuation, describing a factor that is in some sense of "average importance" to the group as a whole, and the higher the value approaching 40, the stronger the concurrence on the "high importance" of a factor. In a similar manner, if the value 1 were assigned by all respondents, the total would be 1 x 8 = **8**, and therefore, regardless of the actual combination that yielded the same total value of 8, it possibly could be interpreted to describe a factor of "lower importance" to the group as a whole. However, in every case in which there are *more than* five factors in a quadrant (9 of the 12 quadrants under consideration), the factors that are not chosen for ranking on the 1-to-5 scale are implicitly valued as "less than 1" in importance by the group, which is worth noting.

Results

In Table A-1, the individual ranking from 1 to 5 from all of the eight quantifiers are recorded *in series* (no punctuation or spaces) in the column called "Rank 1-5. The sum of each series is shown as a point-value sum in red for each corresponding factor, in each impact area, grouped by the categories of strengths, weaknesses, opportunities, and threats. The value of 24 is considered as a mid-range reference point, as described above. There was no consensus (40); the highest degree of concurrence was a value of 32, attained for two among all of the factors considered in all categories—one" strength," and one "weakness." Some factors were not assigned a value by any of the quantifiers.

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[1] Dr. Nicki Mazur, 2010, personal communication, Canberra, Australia.

[2] Sheppard, R. B., 2008, *Gaining a Social License to Mine,* p. 20-23. Situational Analysis, Applied Ecosystem Services Inc. Troutdale, Oregon. Available online: www.mining.com.

Table A-1. **IMTA Summary of SWOT Analysis: Social, Economic, and Ecological Impacts**[a,b,c,d]

Ecological Impacts Group

STRENGTHS

Rank 1-5	Issue and Sum of Ranking (in red)
4455554	nutrient recycling (especially in closed systems) 32
554441	reduced demand for feed from pelagic marine fisheries and terrestrial crops 23
3121134	greater emphasis on quantifying ecological effects 15
13322522	increased farm productivity 20
2133233	increased farm crop diversity 17
24115	application to a variety of environments (e.g., land-based or marine-based) thus alleviating impacts on coastal zones when sited inland 13

WEAKNESSES

Rank 1-5	Issue and Sum of Ranking (in red)
45544541	lack of thorough understanding of environmental impacts 32
5455453	currently emphasizes only high value products and thus less likely to contribute to world food needs (though seaweeds would be an exception) 31
3333324	converts more resilient food webs to more vulnerable food chains 21
42212232	shifts nutrients flows in the environment to reduce natural production 18

OPPORTUNITIES

Rank 1-5	Issue and Sum of Ranking (in red)
115232	more data-driven decision making in aquaculture development 14
4541151	remediation of anthropogenic eutrophication 21
523233	if IMTA increases domestic production, decreased environmental costs (e.g., transportation) of imported seafoods 18
251	aquaculture research platform 8
2534	potentially greater profitability compared to existing aquaculture systems 14
43154	produce products (such as seaweed-based biofuels) that would reduce environmental impacts of fossil fuels 17
4	specialized markets for IMTA products 4
31422	grower collaboration 12

THREATS

Rank 1-5	Issue and Sum of Ranking (in red)
34335352	larger scale applications may have greater environmental impact and thus less social license 28
43453543	potentially lower profitability compared to existing aquaculture systems (in the short term) 31
55544431	not enough public funding (i.e., political will) for developing a network of demonstration and research sites to examine the feasibility of IMTA 31

Economic Impacts Group

STRENGTHS

Rank 1-5	Issue and Sum of Ranking (in red)
241335	efficiency: nutrient uses, coastal space 18
33142431	marketing advantages 21
25451542	new image: differentiated coastal aquaculture 28
15313	diversified products = risk production 13
52225214	operational efficiencies: labor, operational rates, leasing 23
43425	ecosystem services revenue opportunities 18

WEAKNESSES

Rank 1-5	Issue and Sum of Ranking (in red)
55552413	complexity: marketing, operations, juveniles, business planning 30
23114224	risks: structural, disease, operations, seed supply 18
24121145	site-specific criteria (because of multiple species): salinity, current, temperature 20
12335551	greater capital costs for start-up 20
43443332	regulatory complexity 26

OPPORTUNITIES

Rank 1-5	Issue and Sum of Ranking (in red)
3544131	markets: pricing, raise high-value product, packaging, niche opportunities 21
24455542	"sustainable" image 31
1333213	ecosystem services, potential revenue 16
522234	development platform: new products, aquaculture innovations, feed, macroalgae, research 18
51455	use IMTA as launching platform for national aquaculture vision 20
411212	accelerated innovation potential 11
	adaptability: to climate change
3	new partners 3

THREATS

Rank 1-5	Issue and Sum of Ranking (in red)
1544551	social acceptance, public perception 25
525535	natural threats: disease, parasites, storms 25
43323	disappointment of expectations: failures could reflect badly on entire effort 15
214112	market threats: overproduction, price cycles 11
31223	competition from monoculture 11
214	cheap imitation of IMTA 7
4335244	greater regulatory requirements 25
1	new competing users 1

Social Impacts Group

STRENGTHS

Rank 1-5	Issue and Sum of Ranking (in red)
515132	strong brand/green business 14
252	species diversification 7
34	opportunities for business (niche) 7
13	visual perception (of aquaculture operations) 4
44	education 8
422134	ecologically sound 17
422133	healthful food (protein, Omega-3) 10
	scalable
	young industry—new model
551	commerce/jobs/living wages 11
	rewarding enterprise
3	scientific discovery 3
34	preserve working waterfront 7
225	improve environmental condition 9
5	ecosystem services provided 5
4112	year-round production (of multiple species) 8
1	lease revenues 1
5	good stewardship 5

WEAKNESSES

Rank 1-5	Issue and Sum of Ranking (in red)
45342	visual perception (of aquaculture operations) 18
	fear of unknown
3213	poor examples/failures (could color overall perception) 9
311	young industry 5
535535	complexity 26
231	conflict of use (water, space) 6
1124	lack of critical mss 8
32425	capital intensity-scale 16
244	potential to downgrade monoculture 10
12	maybe greater privatization of public resources 3
5415	economic viability 15
4	greater wildlife impacts and public perception

OPPORTUNITIES

Rank 1-5	Issue and Sum of Ranking (in red)
31324	social awareness 13
1231	buy local 7
2441	niches 11
341	increase healthy food supply 8
14	initiating partnerships 5
24	education pathway 6
55	optimize nutrient loads 10
5453	service industry jobs 17
552	eco-food tourism 12
2	regulatory design 2
25	control environment (marketability) 7
41	improved technology 5
351332	opportunity for new, ecologically responsible species under culture 17

THREATS

Rank 1-5	Issue and Sum of Ranking (in red)
32	competition in market 5
2	environmental degradation 2
21412	shoreline development 10
1411	user conflicts/space 7
221524	financing 16
5443	regulation or lack thereof 16
354	"farm-raised" (negative response to the label) 12
1243	uncontrolled messages (e.g., on the Internet) 10
4553355	misinformation 30
35	lack of marine spatial planning 8

a) N=8 quantifiers who participated in the survey.
b) Numbers in red are the sum of rankings (1 through 5) by eight participants.
c) Maximum possible total = 40 (in the case that all eight quantifiers ranked an item as "5").
d) Please see Footnote 2, page 9, concerning a controversial factor in Ecological Impacts—Weaknesses.

Strengths

__Ecological.__ One factor was assigned a value of at least the mid-range, 24: *nutrient recycling (especially in closed systems)* (32).
__Economic__. One value exceeded the mid-range: *new image: differentiated coastal aquaculture* (28).
__Social.__ None of the values equaled mid-range or higher; rather, the values were dispersed among all factors.

Weaknesses

__Ecological.__ One factor exceeded the mid-range: *lack of thorough understanding of environmental impacts* (32).
__Economic.__ Two factors exceeded the mid-range reference point: *complexity: marketing, operations, juveniles, business planning* (30); *regulatory complexity* (26).
__Social.__ One factor exceeded the mid-range reference: *complexity* (26).

Opportunities

__Ecological.__ No factor was valued at or above the mid-range reference point.
__Economic.__ One factor was valued above the reference number: *sustainable image* (31).
__Social.__ No factor was valued at or above the mid-range reference point.

Threats

__Ecological.__ All three factors included in this quadrant were valued at the mid-range or greater: *potentially lower profitability compared with existing aquaculture systems (in the short term)* (31); *not enough public funding (i.e., political will) for developing a network of demonstration and research sites to examine the feasibility of IMTA* (31); *larger scale applications may have greater environmental impact and thus less social license* (28).
__Economic.__ Three of the factors equaled or exceeded the mid-range value: *social acceptance, public perception* (25); *natural threats: disease, parasites, storms* (25); *greater regulatory requirements* (25).
__Social.__ One factor was valued above the reference*: misinformation* (30).

Below, the results from Table A-1 are presented in a graphical format (Figures 1-3), which provides a different perspective, and which may yield further insight, according to Edwin Tufte (1997, 2001).[2]
The individual SWOT quadrants and factors were graphed in two domains: the *frequency* with which a factor was chosen for a value between 1 and 5, and the *sum of the values* assigned to each SWOT factor. The frequency domain demonstrates that not all of the SWOT factors were assigned numerical values, but also that survey respondents chose not to use all of the numerical values to respond in several instances. The sum domain plots show the weight of the relative values for each factor. For clarity, some of the factor titles on the horizontal axis have been abbreviated. Where a unique mode was present for a quadrant, it was noted; however, the frequency domain graph makes the mode clear as the widest band of color in a sector graph—hence, both domains are displayed. If there is more than one mode in a data set, it is less useful as an indicator of central tendency (Tufte 1970).[3]

Respondents could rank only five factors per category; therefore, the fact of *selection* of any factor is as important as its numerical ranking. The total value of the sum, however, may be viewed as a measure of the strength of the *concurrence* of the respondents on a given factor with in the SWOT framework. The small group of respondents was fairly diverse, representing a variety of stakeholder types, and the most significant findings seemed to be reinforced, rather than altered, as data points were added. Finally, we choose to conclude the analysis at this point, given the small sample size of N-8 respondents.

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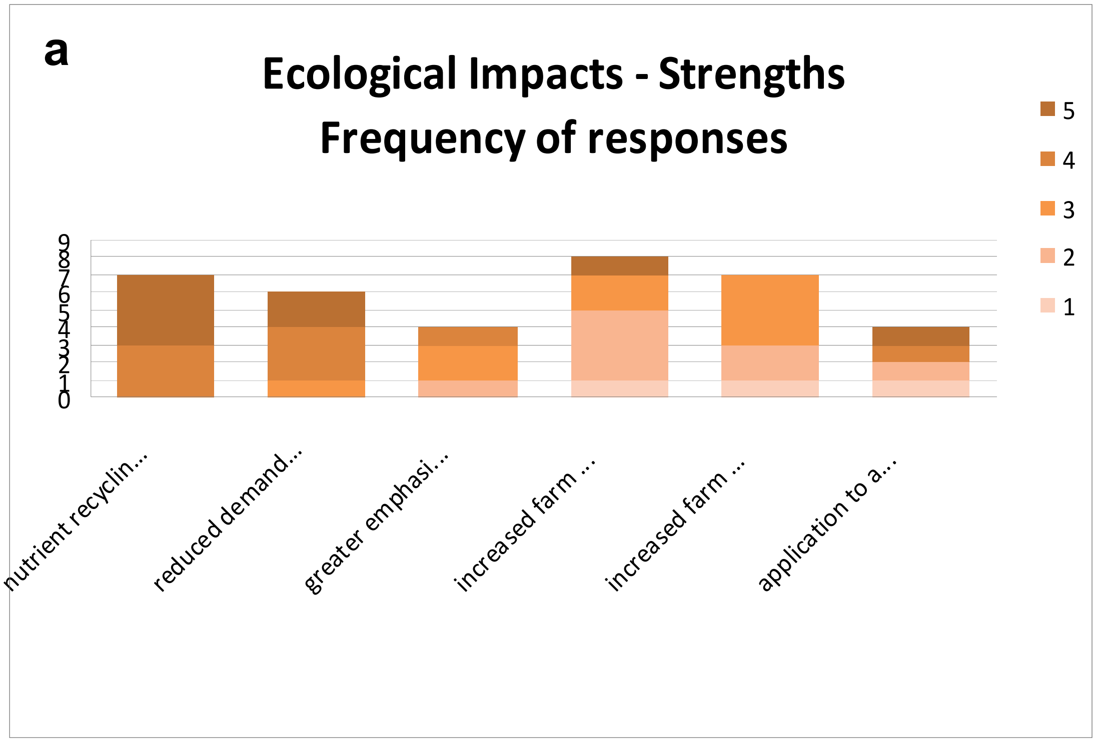
[2]Tufte, E., 1997, Vi*sual Explanations: Images and Quantities, Evidence and Narrative.* Graphics Press, Cheshire, Connecticut; and 2001. *The Visual Display of Quantitative Information.* Graphics Press, Cheshire, Connecticut.

[3] Tufte, E., ed., 1970, *The Quantitative Analysis of Social Problems.* Addison-Wesley, Reading , Massachusetts.



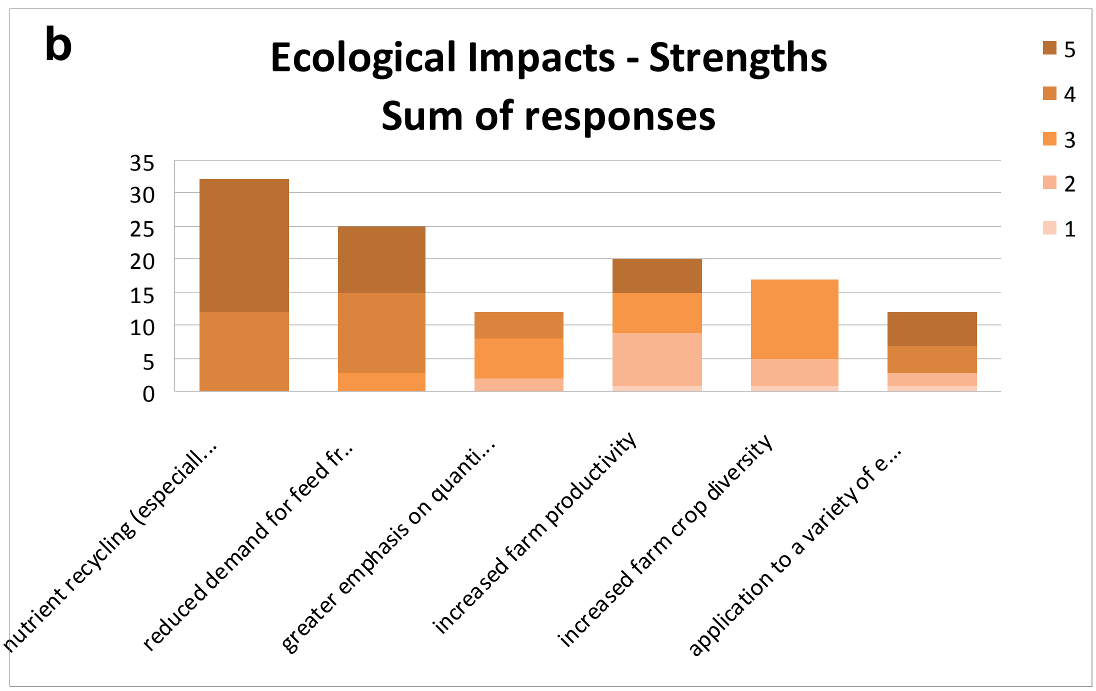
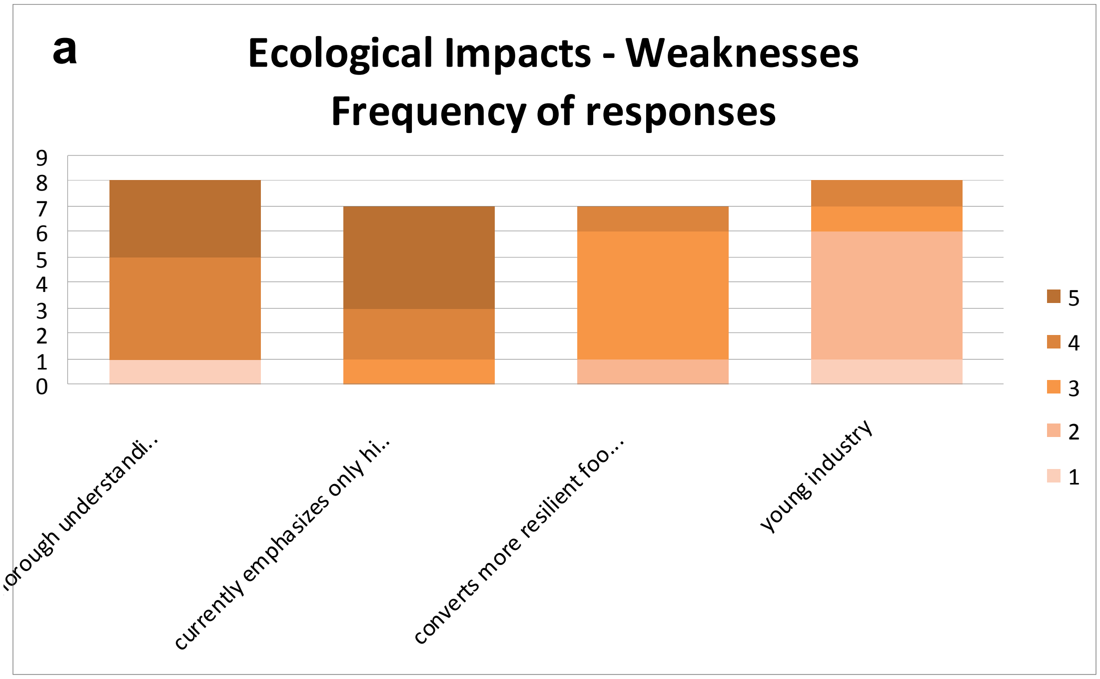


Figure A-1. IMTA Ecological Impacts SWOT survey summary—Strengths: a) frequency of responses; b) sum of responses



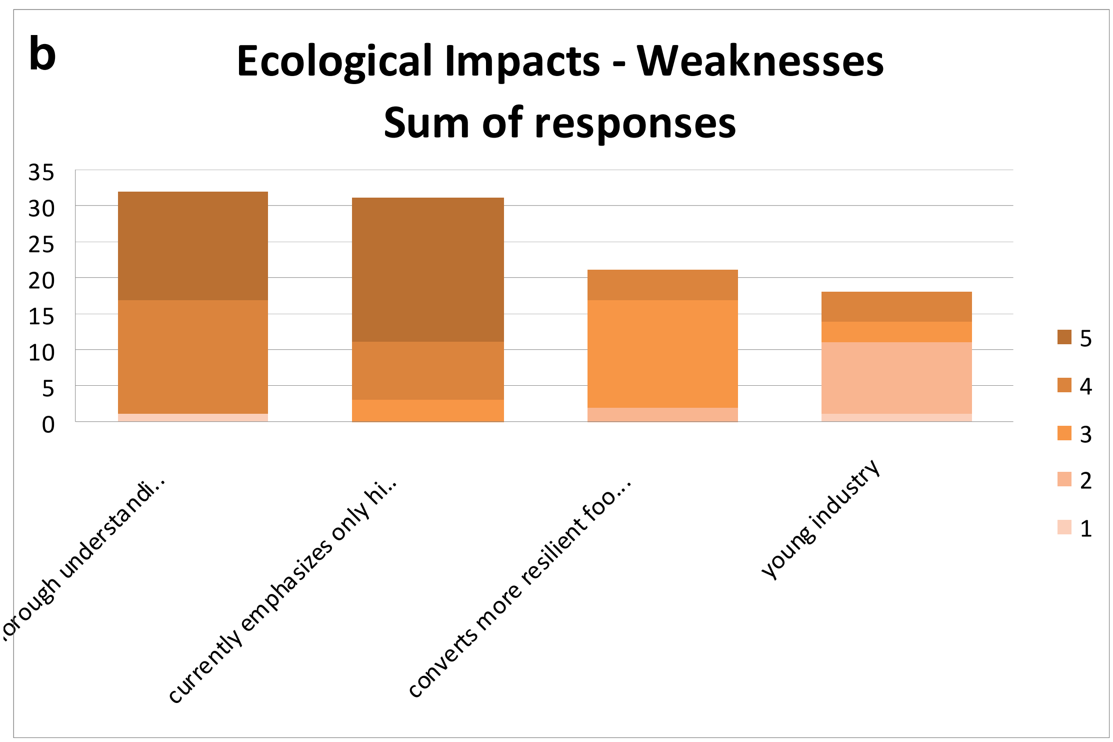
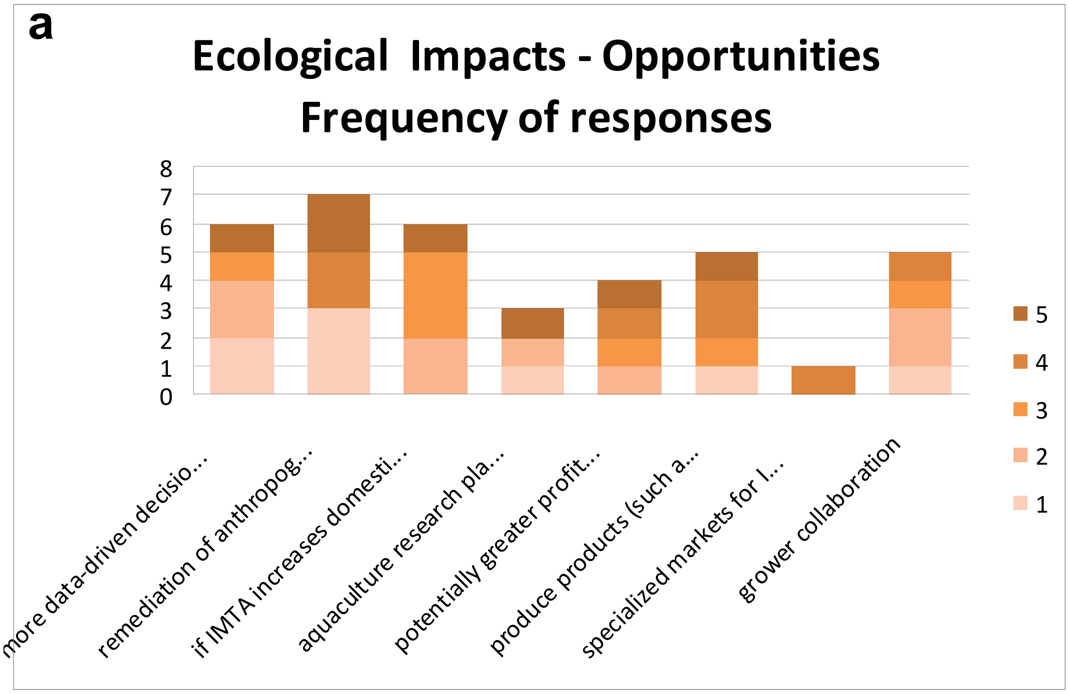


Figure A-2. IMTA Ecological Impacts SWOT survey summary—Weaknesses: a) frequency of responses; b) sum of responses *(please see Footnote 2, page 9, concerning a controversial factor in this category)*



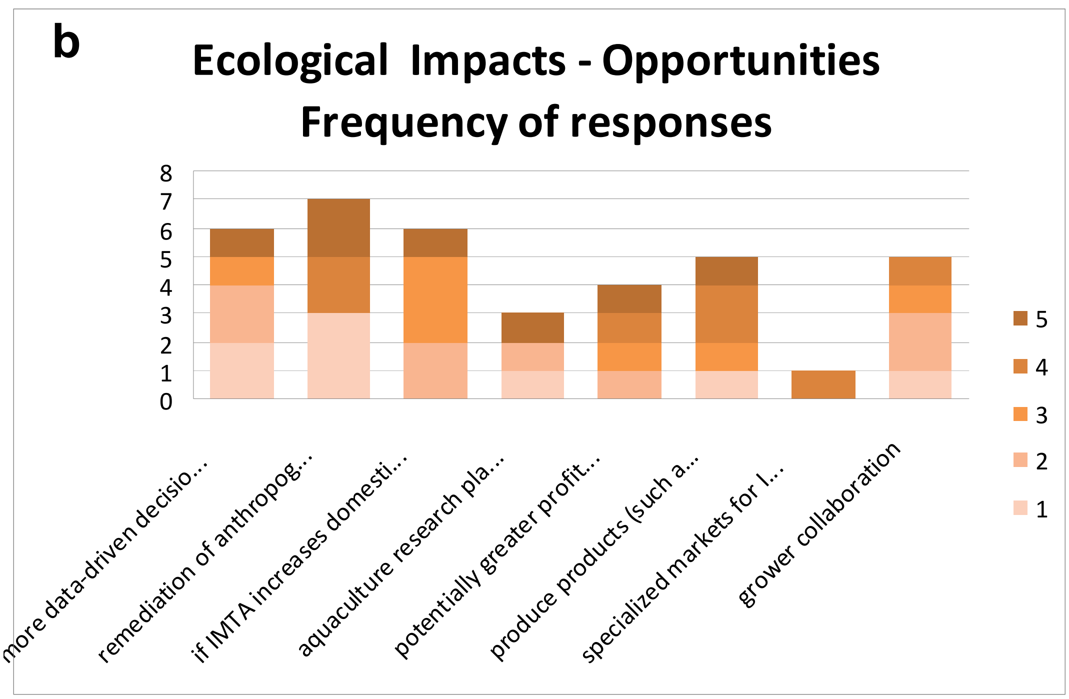
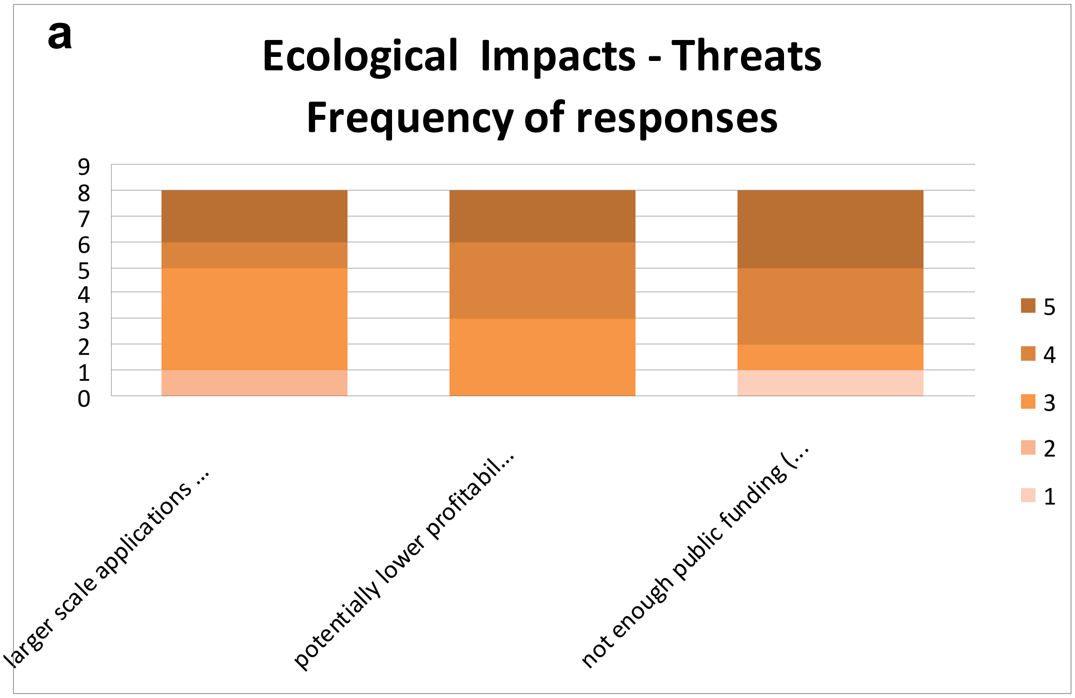


Figure A-3. IMTA Ecological Impacts SWOT survey summary—Opportunities: a) frequency of responses; b) sum of responses



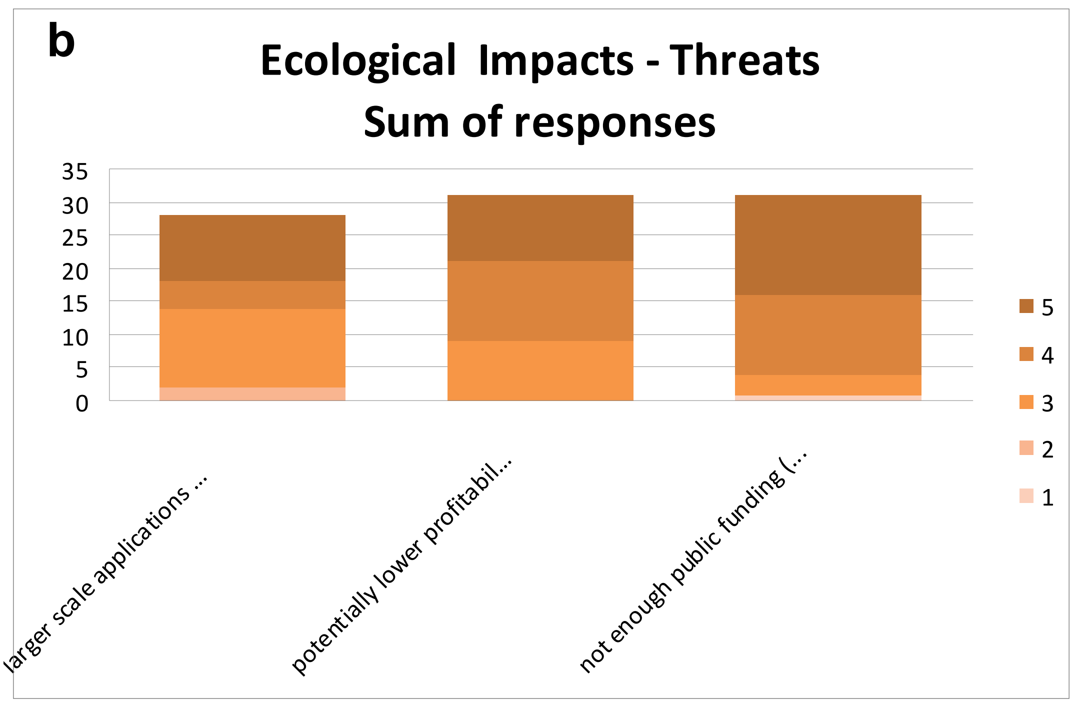


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Figure A-4. IMTA Ecological Impacts SWOT survey summary—Threats: a) frequency of responses; b) sum of responses

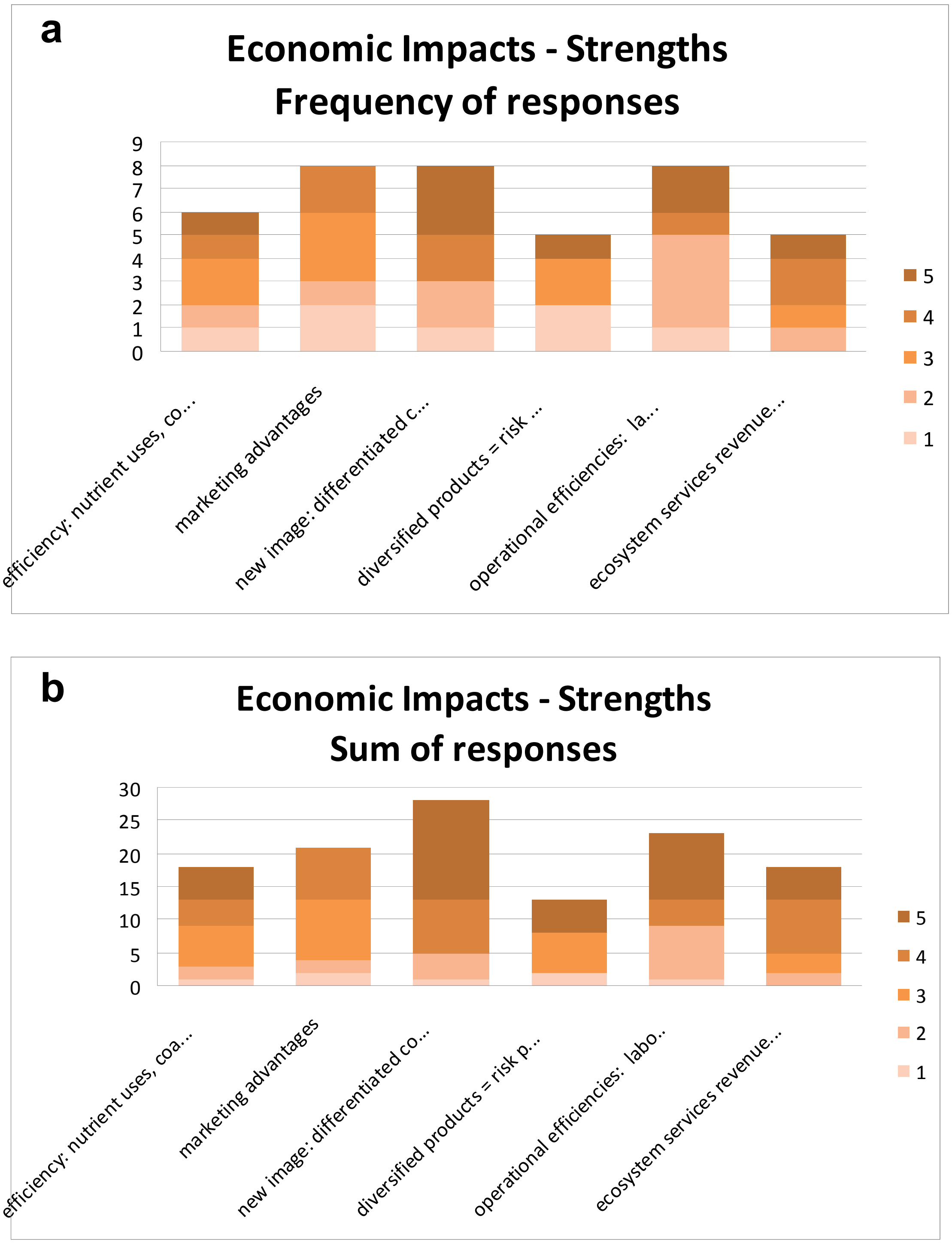
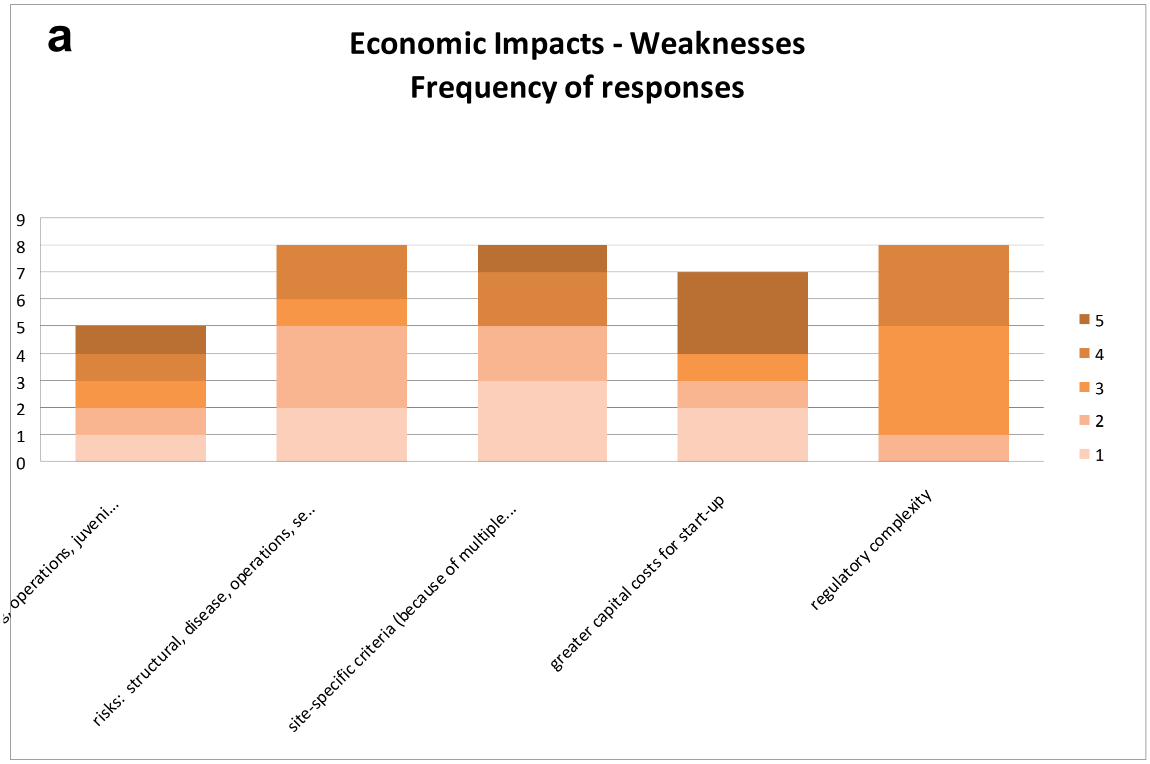


Figure A-5. IMTA Economic Impacts SWOT survey summary—Strengths: a) frequency of responses; b) sum of responses



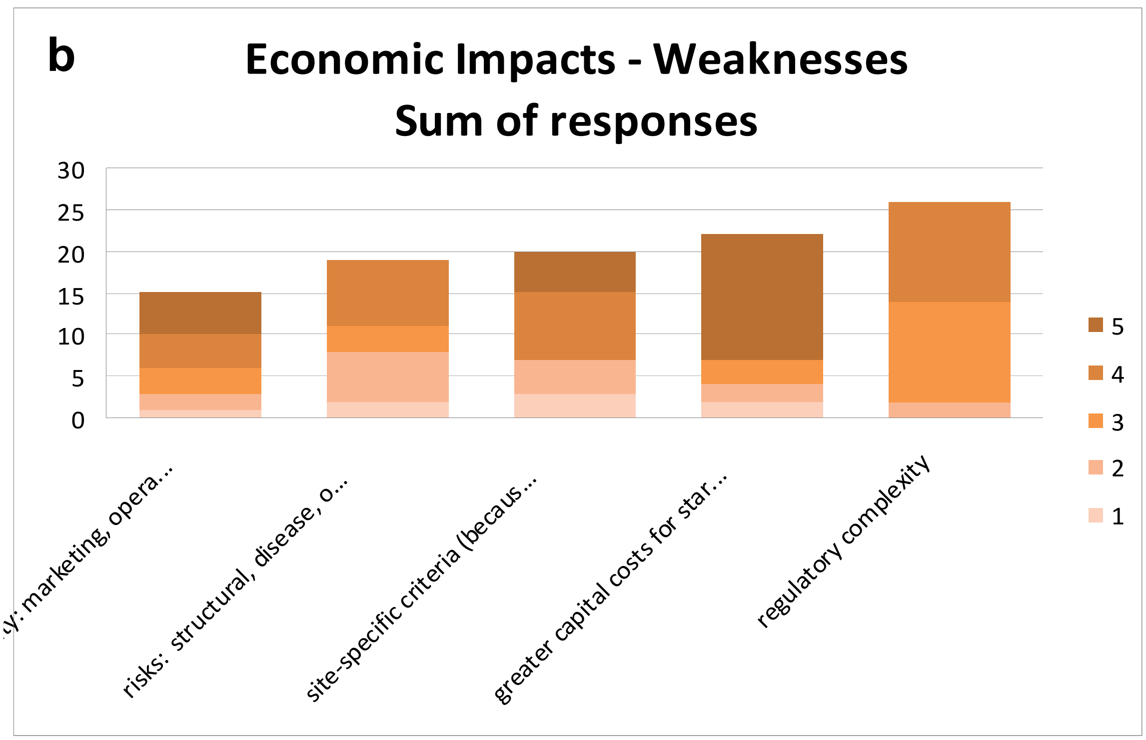
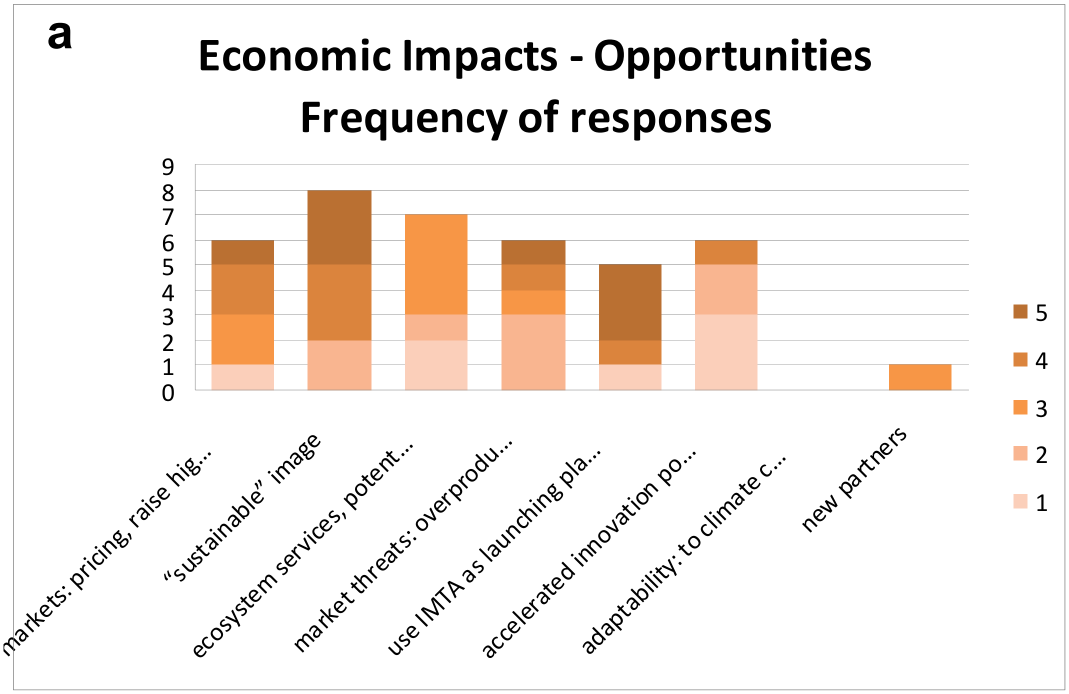


Figure A-6. IMTA Economic Impacts SWOT survey summary—Weaknesses: a) frequency of responses; b) sum of responses



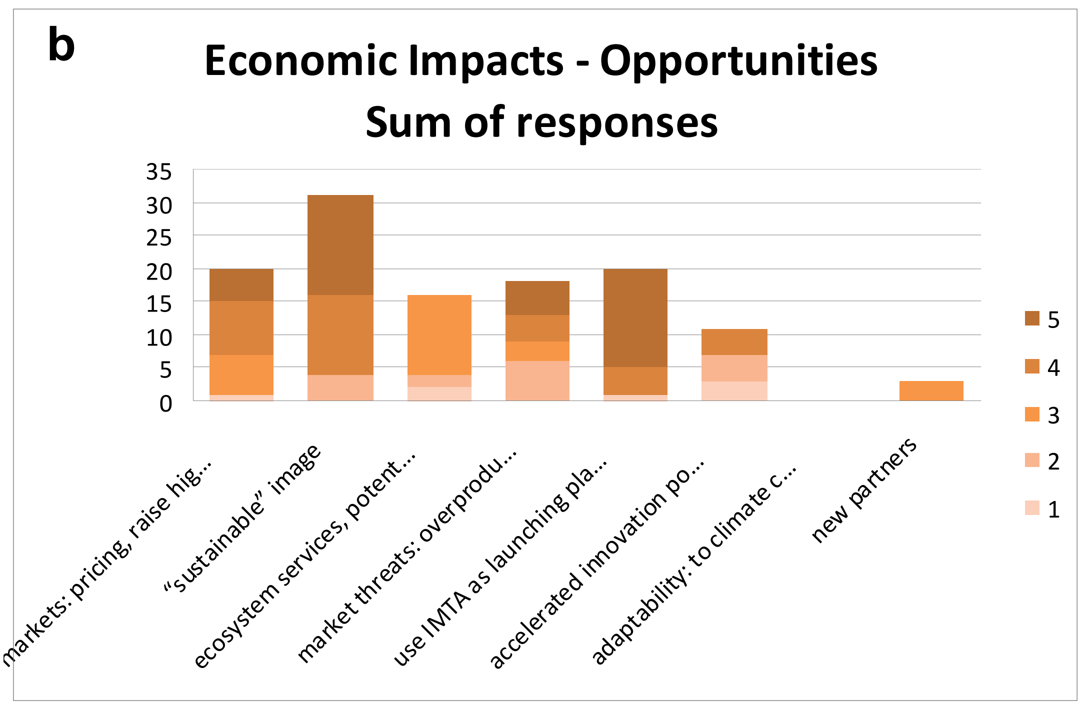
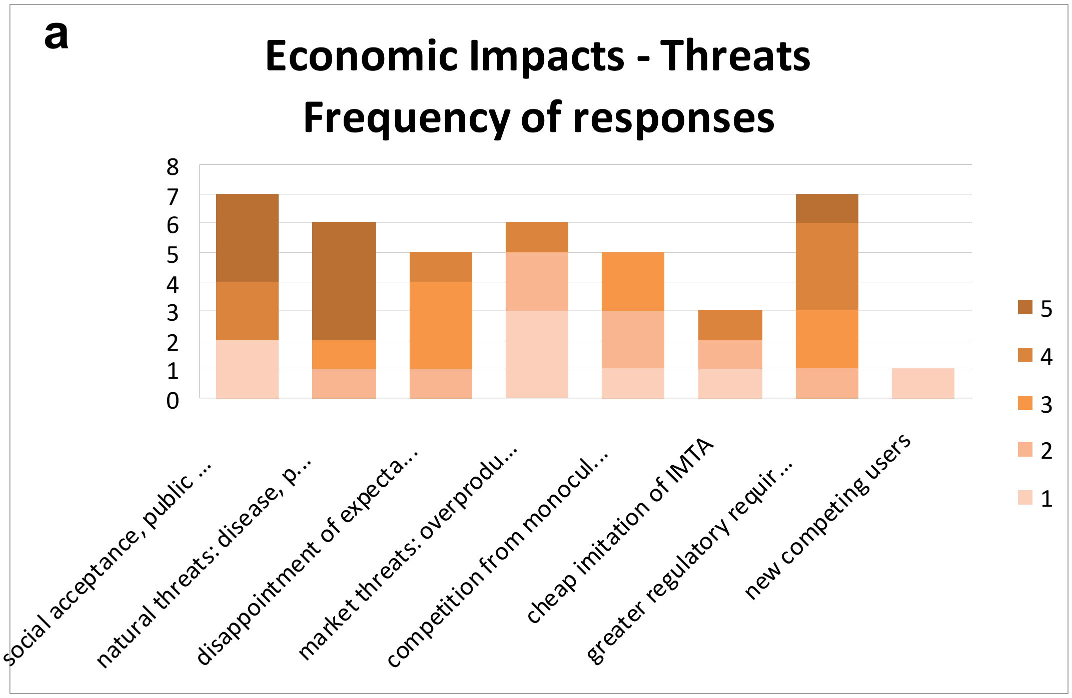


Figure A-7. IMTA Economic Impacts SWOT survey summary—Opportunities: a) frequency of responses; b) sum of responses



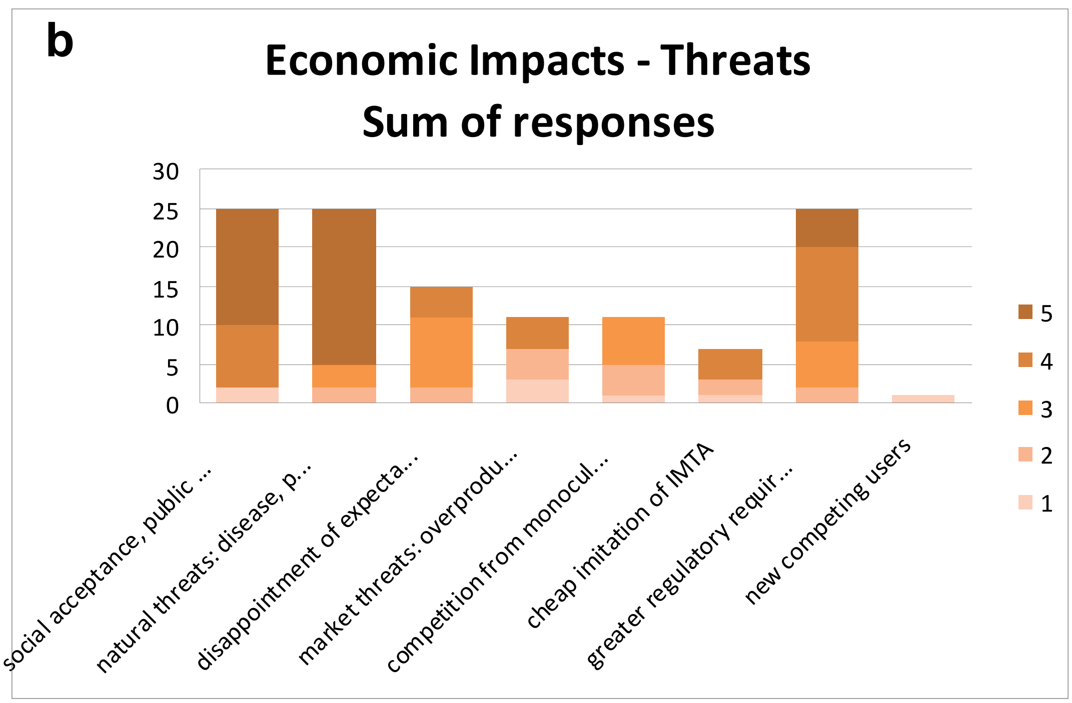
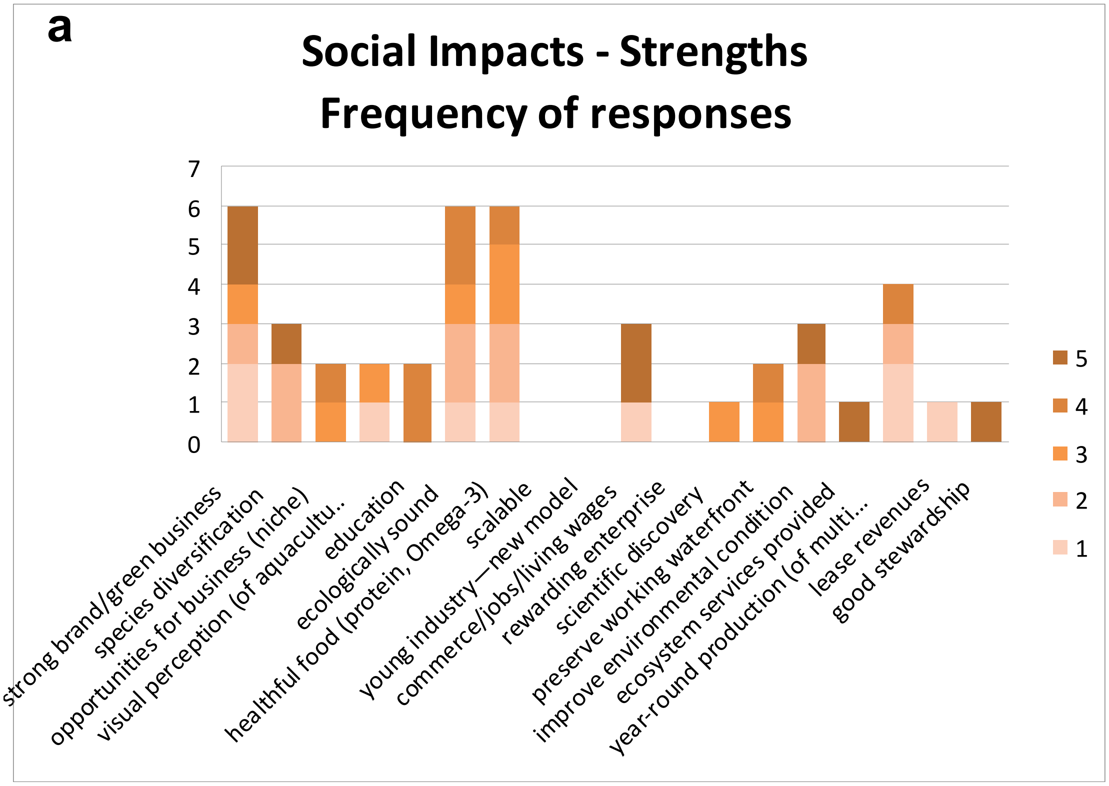


Figure A-8. IMTA Economic Impacts SWOT survey summary—Threats: a) frequency of responses; b) sum of responses



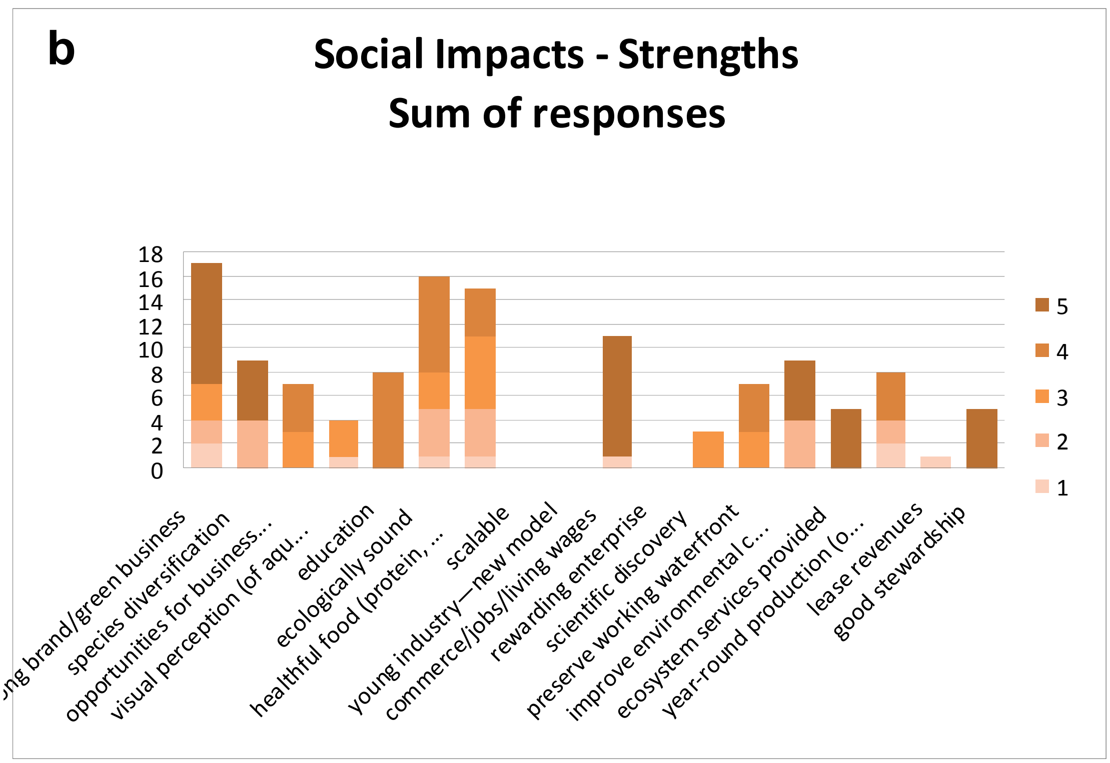
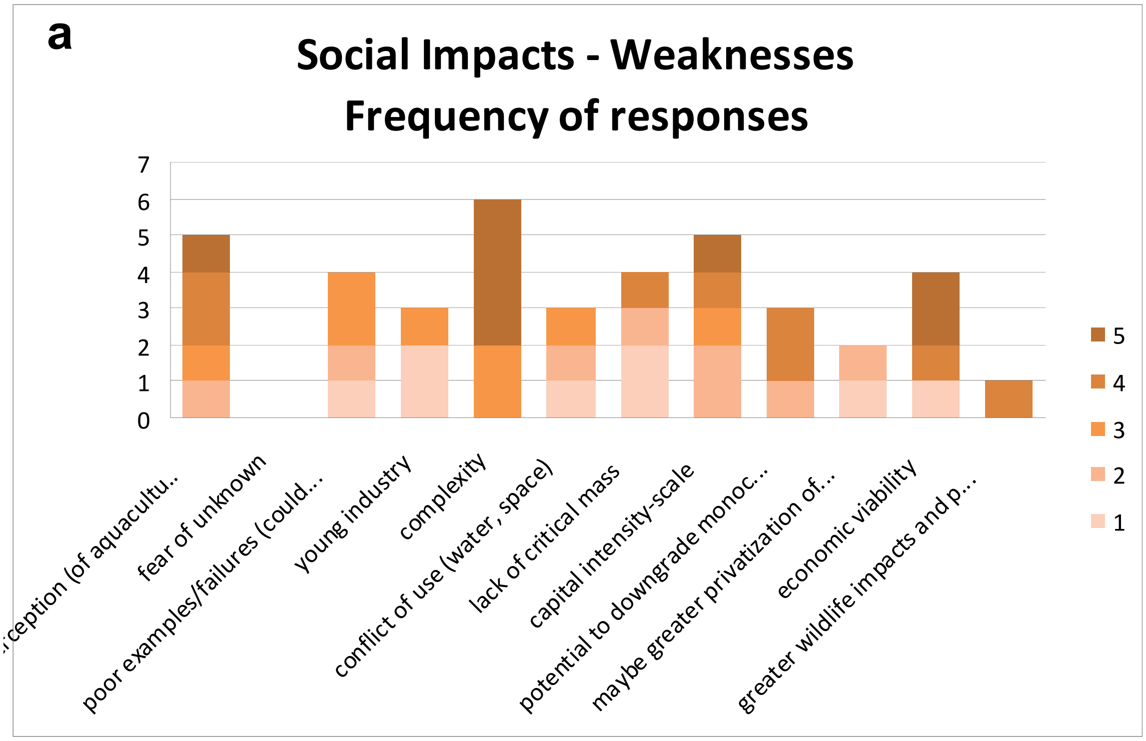


Figure A-9. IMTA Social Impacts SWOT survey summary—Strengths: a) frequency of responses; b) sum of responses



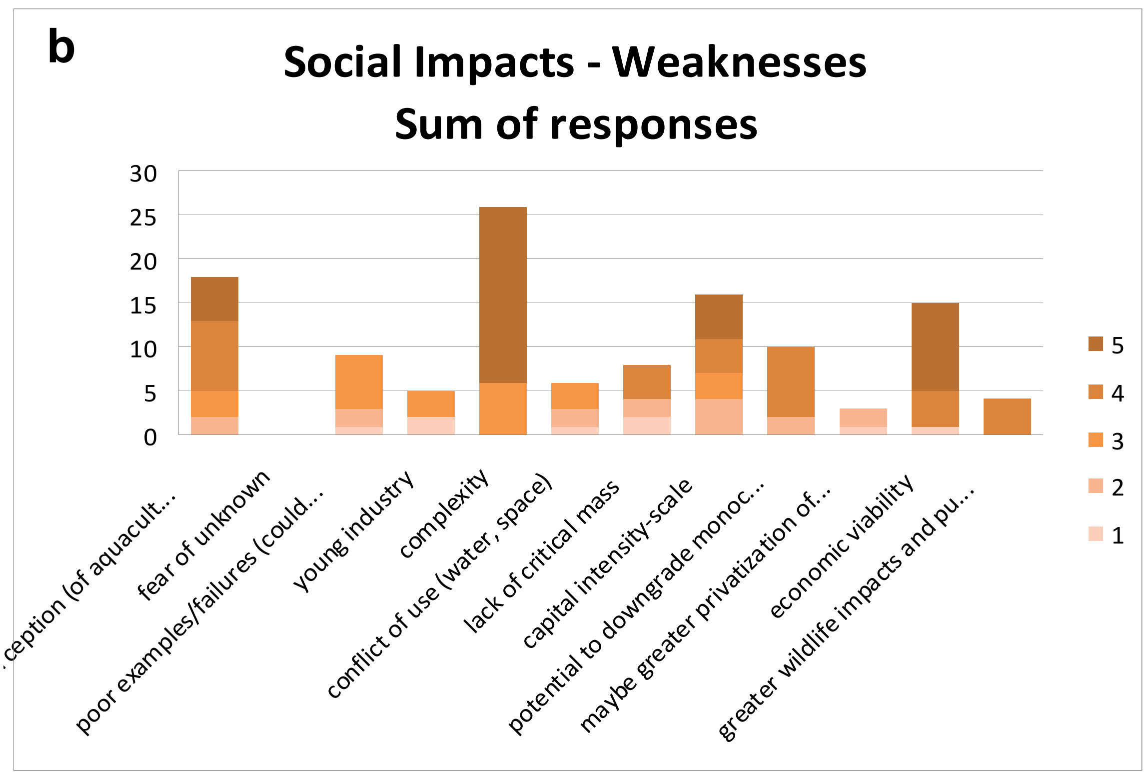
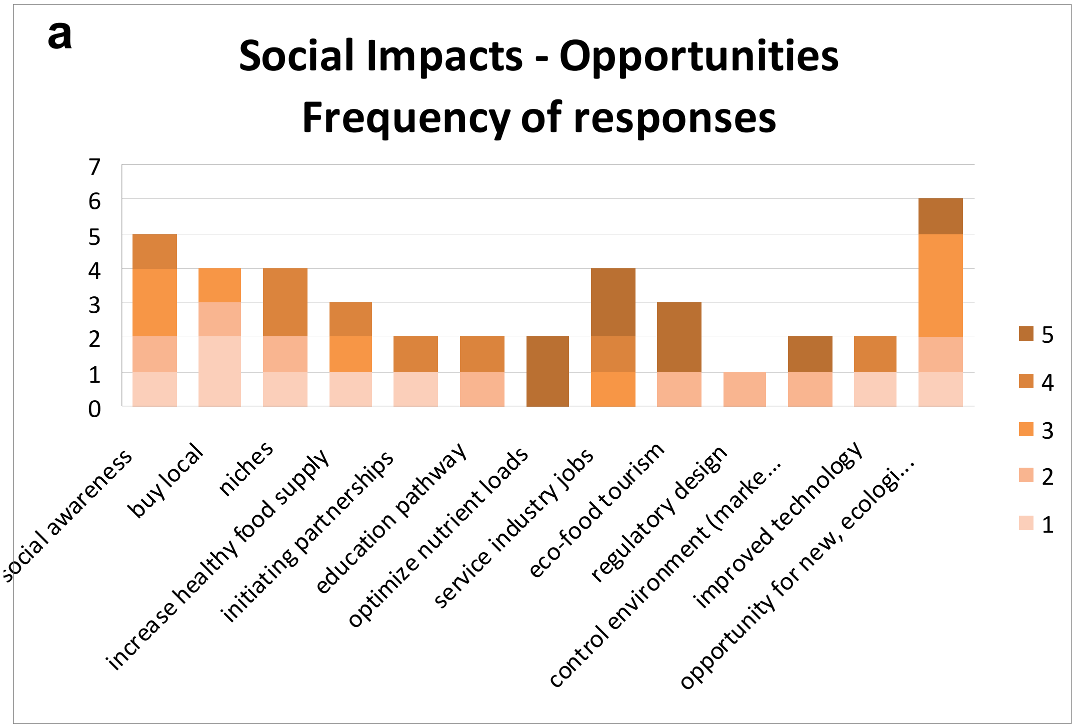


Figure A-10. IMTA Social Impacts SWOT survey summary—Weaknesses: a) frequency of responses; b) sum of responses



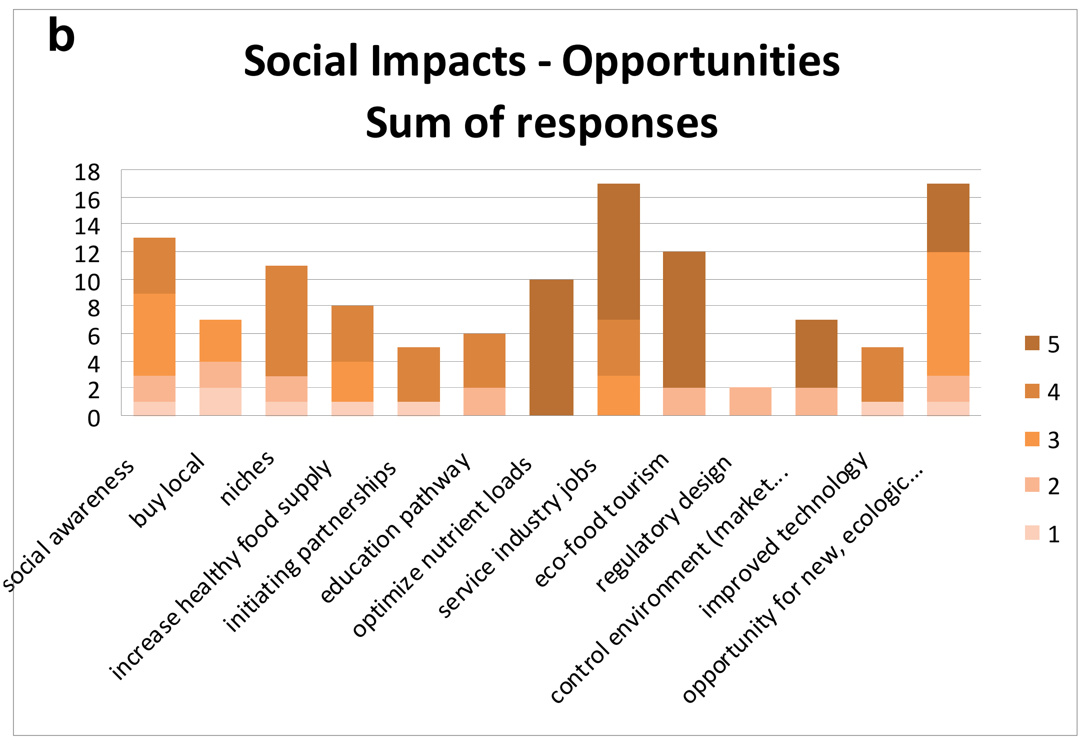
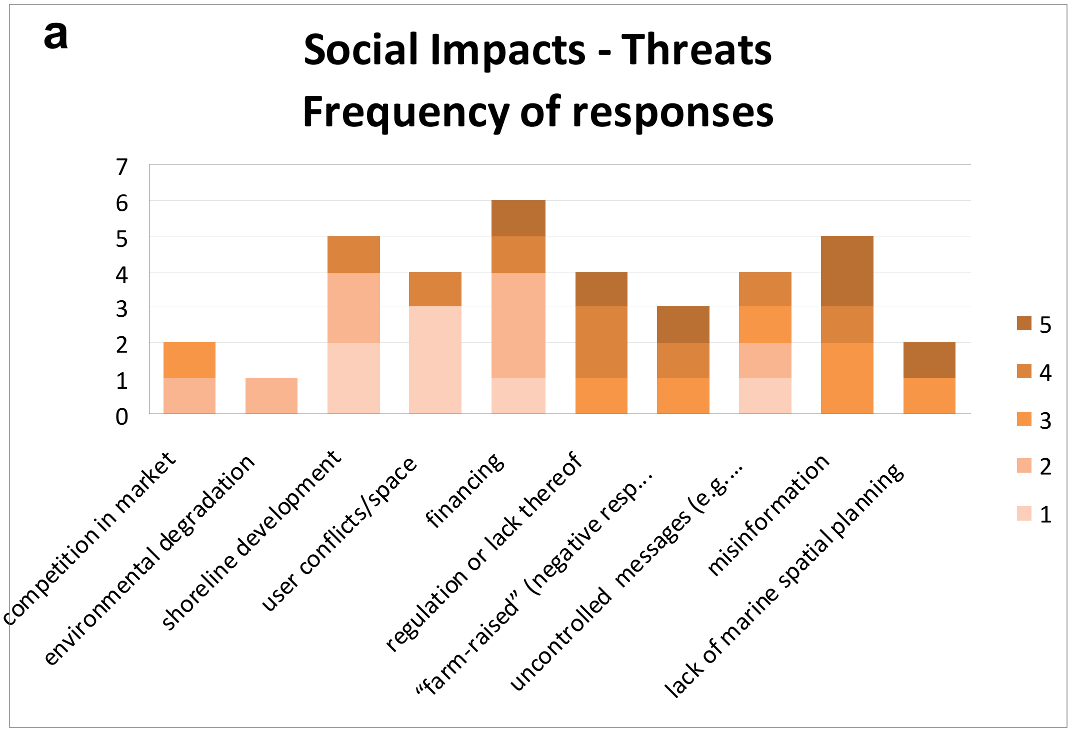


Figure A-11. IMTA Social Impacts SWOT survey summary—Opportunities: a) frequency of responses; b) sum of responses



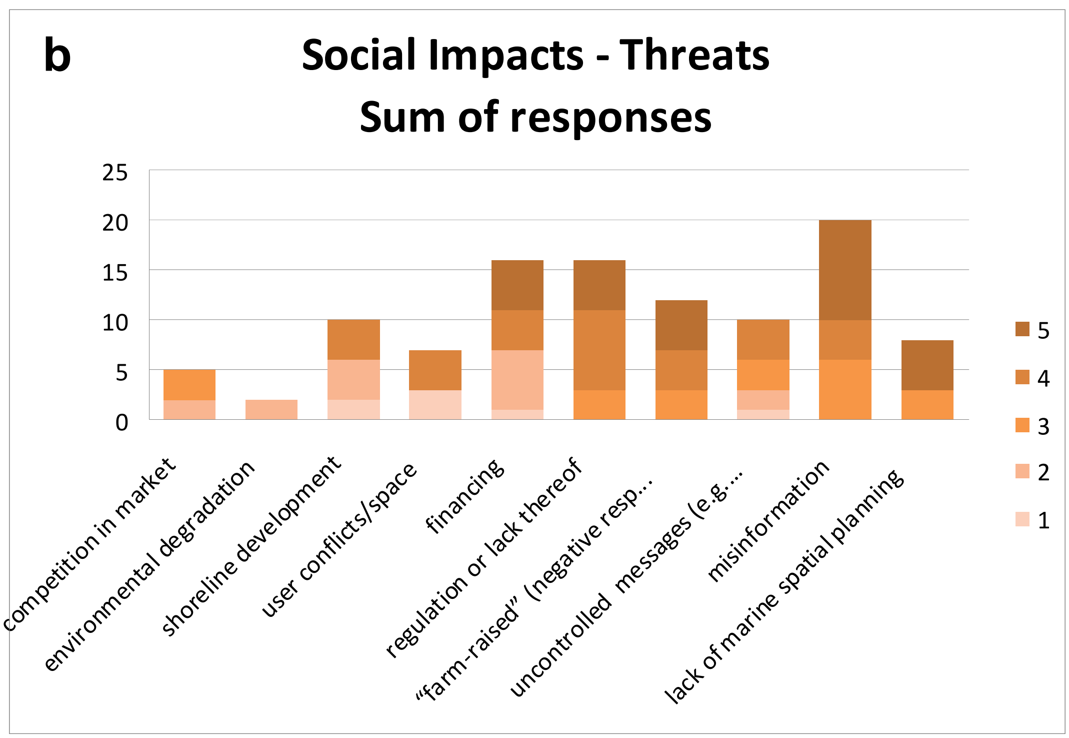


Figure A-12. IMTA Social Impacts SWOT survey summary—Threats: a) frequency of responses; b) sum of responses

APPENDIX IV
PUBLIC COMMENT

Comment from Paul Zajicek, submitted on 2011/05/02 at 5:32 am

I liked the paper and very much appreciate the huge effort that was invested in the workshop, organizing speakers, and producing the summary. Very, very impressive.

Please accept my comments in the constructive way that they are intended.

As impressive as the title is, integrated multi-trophic aquaculture, it is emblematic of a comment expressed at the workshop: complex, difficult to understand and difficult to communicate. Suggest something that most Americans with our rudimentary science education can grasp: Food Web Aquaculture. Yes it is not perfect but it does provide a mental image and platform for easier explanation.

As an alternative consider linking the terms: IMTA: Food Web Culture. Or something to that effect.

A consumer trend being missed by most aquaculturists is a growing interest in aquaponics that is sweeping the nation. It is quite unbelievable where these systems are popping up, micro and macro in size, but this production system fits a number of current US interests: local food, safe food, DIY, etc. Aquaponics is IMTA and that should be acknowledged in the paper.

It would be a good stroke if more effort was given to explaining the SWOT analysis. Residing in the colored boxes is the response to the rest of my comments which are enterprise focused rather than concept focused which appears to have been the level at which the workshop was explained.

Consider adding a section that discusses applicability. For a variety of valid reasons not all systems or managers will be able to adopt an IMTA structure which requires careful planning, design, and manage of the production system but also investment of time, energy, and money into a marketing plan that addresses vastly different markets. It will be a rare farm manager that can successfully juggle hugely different markets.

If ever there was a prescription for a management team this is it. It should also be clearly stated that a farm predicated on IMTA will only succeed if the goal is enterprise success and not fish, plant, or shellfish success. As a critical component of that team management there must be a means to objectively evaluate the economic contribution of each production component to the enterprise.

Unfortunately, as is usually the case that folks that have fallen in love with a concept also work very hard to insure its adoption without fully describing for nonadherents some of the critical issues that insure success. It does not appear that participants were really asked about IMTA nuts and bolts so there may be an opportunity for PACA to fill that void.