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REVIEWS IN Aquaculture

Reviews in Aquaculture (2016) 0, 1–16 doi: 10.1111/raq.12140

Ocean acidification and marine aquaculture in North America: potential impacts and mitigation strategies

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Received 2 September 2015; accepted 16 December 2015.

Abstract

Shifting environmental conditions resulting from anthropogenic climate change have recently garnered much attention in the aquaculture industry; however, ocean acidification has received relatively little attention. Here, we provide an overview of ocean acidification in the context of North American aquaculture with respect to potential impacts and mitigation strategies. North American shellfish farms should make ocean acidification an immediate priority, as shellfish and other calcifying organisms are of highest concern in an increasingly acidifying ocean and negative effects have already been felt on the Pacific coast. While implications for various finfish have been documented, our current understanding of how acidification will impact North American finfish aquaculture is limited and requires more research. Although likely to benefit from increases in seawater CO_2, some seaweeds may also be at risk under more acidic conditions, particularly calcifying species, as well as non-calcifying ones residing in areas where CO_2 is not the primary driver of acidification. Strategies to mitigate and adapt to the effects of acidification exist on the regional scale and can aid in identifying areas of concern, detecting changes in seawater carbonate chemistry early enough to avoid catastrophic outcomes, and adapting to long-term shifts in oceanic pH. Ultimately, ocean acidification has already imposed negative impacts on the aquaculture industry, but can be addressed with sufficient monitoring and the establishment of regional mitigation plans.

Key words: finfish aquaculture, mitigation, ocean acidification, seaweed aquaculture, shellfish aquaculture.

Introduction

One of the fastest growing global food sectors is the aquaculture industry. In 2012, aquaculture accounted for more than 40% of the total production of finfish and invertebrates from capture fisheries and aquaculture combined, yielding 90.4 million tonnes of product and revenue upwards of USD$144 billion (FAO 2014). Furthermore, aquaculture accounts for more than 95% of global commercial seaweed production, producing 23.8 million tonnes in 2012 (USD$6.4 billion) (Chopin 2014). Although not as large as in other parts of the world, North American total aquaculture (marine and freshwater) produced 393 496 metric tonnes of food in 2012, highlighting its important role in local and global food production (FAO 2014).

Marine aquaculture in North America is mostly taking place in Canada. In 2013, Canada produced 172 097 metric tonnes of farmed seafood, valued at CAD$962.9 million (Chopin 2015a). Canada's total finfish aquaculture production in 2013 was 130 357 tonnes, valued at CAD $870.3 million, representing 75.7% of the volume and 90.4% of the value of the total Canadian aquaculture production. Farmed salmon, by far the most important finfish grown by Canadian aquaculturists, accounted for 76.7% of the volume and 72.9% of the value of finfish produced in 2013, with a production volume of 100 027 tonnes valued at CAD$634.2 million. Other finfish species currently undergoing aquaculture development or being cultivated on a smaller scale include sablefish, sturgeon, rainbow trout, steelhead trout, halibut and arctic char. Canada's total shellfish aquaculture production in 2013 was 41 760

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Jeff Clements and **Thierry Chopin** published a paper in ***Reviews in Aquaculture*** entitled **Ocean acidification and marine aquaculture in North America: potential impacts and mitigation strategies**.

Shifting environmental conditions resulting from anthropogenic climate change have recently garnered much attention in the aquaculture industry; however, ocean acidification has received relatively little attention. This is why Clements and Chopin embarked on this review, in the context of North American aquaculture, not only to look at potential impacts, but also to identify mitigation strategies.

North American shellfish farms should make ocean acidification an immediate priority, as shellfish and other calcifying organisms are of highest concern in an increasingly acidifying ocean and negative effects have already been felt on the Pacific coast. While implications for various finfish have been documented, our current understanding of how acidification will impact North American finfish aquaculture is limited and requires more research. Although likely to benefit from increases in seawater CO_2, some seaweeds may also be at risk under more acidic conditions, particularly calcifying species, as well as non-calcifying ones residing in areas where CO_2 is not the primary driver of acidification.

Strategies to mitigate and adapt to the effects of acidification, including IMTA, exist on the regional scale and can aid in identifying areas of concern, detecting changes in seawater carbonate chemistry early enough to avoid catastrophic outcomes, and adapting to long-term shifts in oceanic pH. Ultimately, ocean acidification has already imposed negative impacts on the aquaculture industry, but can be addressed with sufficient monitoring and the establishment of regional mitigation plans.

Read the paper:

Clements, J., and Chopin, T., 2016 - Ocean acidification and marine aquaculture in North America: potential impacts and mitigation strategies. *Reviews in Aquaculture* 0: 1-16. doi: 10.1111/raq.12140

For the second time, **CIMTAN biologists**, convinced of the power of **interdisciplinary studies**, ventured into the world of **economists** to put a value on the biomitigation benefits of IMTA in Canada.

In 2015, a contingent behaviour analysis, led by **Roberto Martinez-Espiñeira**, from Memorial University of Newfoundland, was published in ***Aquaculture***. It estimated that the aggregate benefit current salmon consumers in Canada would derive from the introduction of IMTA salmon would be about CAD 280 million/year (less restrictive assumptions about the representativeness of the sample would lead to an aggregate figure of about CAD 1.5 billion/year).

The same team of co-authors has just published a contingent valuation analysis in ***Aquaculture Economics & Management***. It found that the benefits accruing to households, who do not purchase salmon habitually, would range between about CAD 43 million/year and about CAD 65 million/year.

As such, the economic and societal implications of the adoption of IMTA practices are not negligible. To give IMTA its full value, extractive species (such as seaweeds and invertebrates) will have to be valued for not only their biomass and food trading values, but also for the ecosystem services they render and the increase in consumer trust and societal/political license to operate they provide. The IMTA multi-crop diversification approach could also be an economic risk mitigation and management option to address climate change impacts.


AQUACULTURE ECONOMICS & MANAGEMENT
2016, VOL. 20, NO. 1, 1–23
http://dx.doi.org/10.1080/13657305.2016.1124935

Taylor & Francis

A contingent valuation of the biomitigation benefits of integrated multi-trophic aquaculture in Canada

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ABSTRACT
Integrated multi-trophic aquaculture (IMTA) is the farming, in proximity, of aquaculture species from different trophic levels and with complementary ecosystem functions. IMTA allows one species' unaeten feed and wastes, nutrients, and by-products to be recaptured and converted into fertilizer, feed, and energy for the other crops. By taking advantage of synergistic interactions between species, IMTA can help aquaculture evolve towards more responsible and sustainable systems. This study uses data from a contingent valuation survey to provide an estimation of the non-use benefits that, in the form of biomitigation of the external costs imposed on the marine environment, would be derived by Canadians from the adoption of IMTA for Atlantic salmon aquaculture. We find the benefits accruing to households who do not purchase salmon habitually would range between about $43 million/year and about $65 million/year for the next five years, depending on the treatment of 'don't know' responses to the payment question.

KEYWORDS
Contingent valuation; integrated multi-trophic aquaculture; willingness to pay

Introduction

Facing an increasing demand for seafood and a declining availability of wild species and stocks, the world is increasingly turning to aquaculture as the main source of seafood supply. Globally, the production through aquaculture of all aquatic species has grown at an average rate of nearly 10% a year for the last three decades (Ayer et al., 2009), accounting now for about half of the total seafood used for direct human consumption (FAO, 2011).

However, concerns have also been expressed about the environmental impacts of aquaculture (e.g., Olesen et al., 2011). These include discharge of wastes, increasing concentrations of nutrients (mainly nitrogen and phosphorus), pathogens and chemicals, and the potential impact that the

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Read the papers:
Martínez-Espiñeira, R., Chopin, T., Robinson, S., Noce, A., Knowler, D., and Yip, W., 2015 - Estimating the biomitigation benefits of integrated multi-trophic aquaculture: a contingent behaviour analysis. *Aquaculture* 437: 182-194.

Martínez-Espiñeira, R., Chopin, T., Robinson, S., Noce, A., Yip, W., and Knowler, D., 2016 - A contingent valuation of the biomitigation benefits of integrated multi-trophic aquaculture in Canada. *Aquaculture Economics & Management* 20 (1): 1-23.

Two articles in **Hatchery International** covered **IMTA related activities**.


Terralynn Lander checking larvae at the prototype sea urchin hatchery at the St. Andrews Biological Station (photo credit: Suzanne Taylor).

In the **November/December 2015** issue, **Terralynn Lander**'s work on developing a **prototype sea urchin hatchery**, with **Shawn Robinson**, at the **St. Andrews Biological Station** (Fisheries and Oceans Canada) was featured. IMTA is the motivation behind this effort, as the green sea urchin (*Strongylocentrotus droebachiensis*) is one of the species that could be cultivated as part of the deposit extractive component of IMTA systems in Atlantic Canada. In addition to being another extractive species on the ocean bottom to reduce the environmental footprint of salmon aquaculture, it is hoped that it will provide potential income for the growers.
After they reach the juvenile stage, the sea urchins nutritional needs change and they start feeding on young shoots of kelps and other soft seaweeds, which would create another application for using the seaweeds produced as the inorganic extractive component of IMTA systems.

Read the article:
http://hatcheryinternational.com/research/mta-the-motivation-for-prototype-sea-urchin-hatchery/

In the **January/February 2016** issue, **Thierry Chopin**, **Stacy Murray** and **Hamid Khoda Bakhsh** published an article entitled **Freshwater IMTA - Developing Integrated Multi-Trophic Aquaculture systems for commercial salmon hatcheries**.

IMTA is a flexible concept on which many variations can be developed and should not be viewed as confined to open-water, marine systems. For instance, Atlantic salmon reared for commercial use spend the early part of their life cycle in freshwater, often in land-based, closed-containment hatcheries before being transferred to open-seawater sites.

From left to right: Hamid Khoda Bakhsh, Stacy Murray and Thierry Chopin looking at their first FIMTA production (photo credit: Adrian Hamer).

FIMTA floating raft grow-beds showing yarrow, mint, lettuce, chamomile and nasturtium after six weeks of growth at 13-15 °C in effluent collected at a commercial salmon hatchery (photo credit: Thierry Chopin).

Consequently, the principles of IMTA can also be applied to land-based, closed-containment and freshwater systems (also called aquaponics). What is important is that the appropriate co-cultured organisms be chosen at multiple trophic levels based on their complementary functions, as well as their economic value.

As in saltwater operations, the nutritional benefits of the water that has been used to grow fish need to be considered. Rather than treating and releasing this water and losing this potential, wastewater becomes a source of irrigation water, nutrients and media for additional crops. A pilot scale freshwater IMTA (FIMTA) system was designed at the University of New Brunswick in Saint John and used to test the growth and nutrient absorption capability of a variety of plants under hatchery conditions. So far, 11 species of plants have been successfully selected with significant nutrient recovery and abatement levels in the effluent.

Read the article

Freelance writer **Claire Eamer** wrote an interesting article, entitled **Seaweed Economics 101: Boom and Bust in the North Atlantic**, in **Haika Magazine**, a magazine which explores science, society and the environment from a coastal perspective.

Coastal communities, on both sides of the Atlantic Ocean, have watched the economic pendulum – and their futures – swing wildly when it comes to relying on seaweed as an industry. Claire is wondering if a better way is finally emerging. To try to find an answer, she interviewed four individuals involved in the revival of the seaweed industry: Jon Funderud, the chief executive officer of Seaweed Energy Solutions (SES), based in Trondheim, Norway; Thierry Chopin, the scientific director of CIMTAN, based in Saint John, Canada; Aleksander Handå, research manager at SINTEF,

also based in Trondheim; and Thorgeir Samuelson, the foreman of Thorverk HF, a manufacturer of organic seaweed-based fertilizer in Reykhólar, Iceland.

In her article, Claire takes the reader on a trip to Europe, Iceland and North America and through several centuries of coastal economies in which seaweeds played a key role through a succession of different applications and markets, following a cycle of booms and busts.
The future appears to be seaweed cultivation at the appropriate scale and the adoption of the Integrated Sequential BioRefinery (ISBR) concept for product and application diversification. Attitudes and business models will need to evolve from the one species – one process – one product approach, too often used with fishery and aquaculture products, to move towards the one species – several processes – several products approach. On one hand, seaweeds can yield a wide range of bio-based, high-value compounds (edible food, food and feed ingredients, biopolymers, fine and bulk chemicals, agrichemicals, cosmetics, bioactives, pharmaceuticals, nutraceuticals, botanicals, etc.). On the other hand, lower-value commodity bioenergy compounds (biofuels, biodiesels, biogases, bioalcohols, biomaterials, fibers, heat/power, etc.) can also be generated from seaweeds.
Over the last decade, the IMTA group in Atlantic Canada has adopted this ISBR diversification strategy: IMTA kelps recapture some of the inorganic dissolved nutrients from fish farms, and markets are being developed for kelp use in human consumption, beer, cosmetics, fish and sea urchin feed, and biochar production, along with eco-labelling and organic certification.

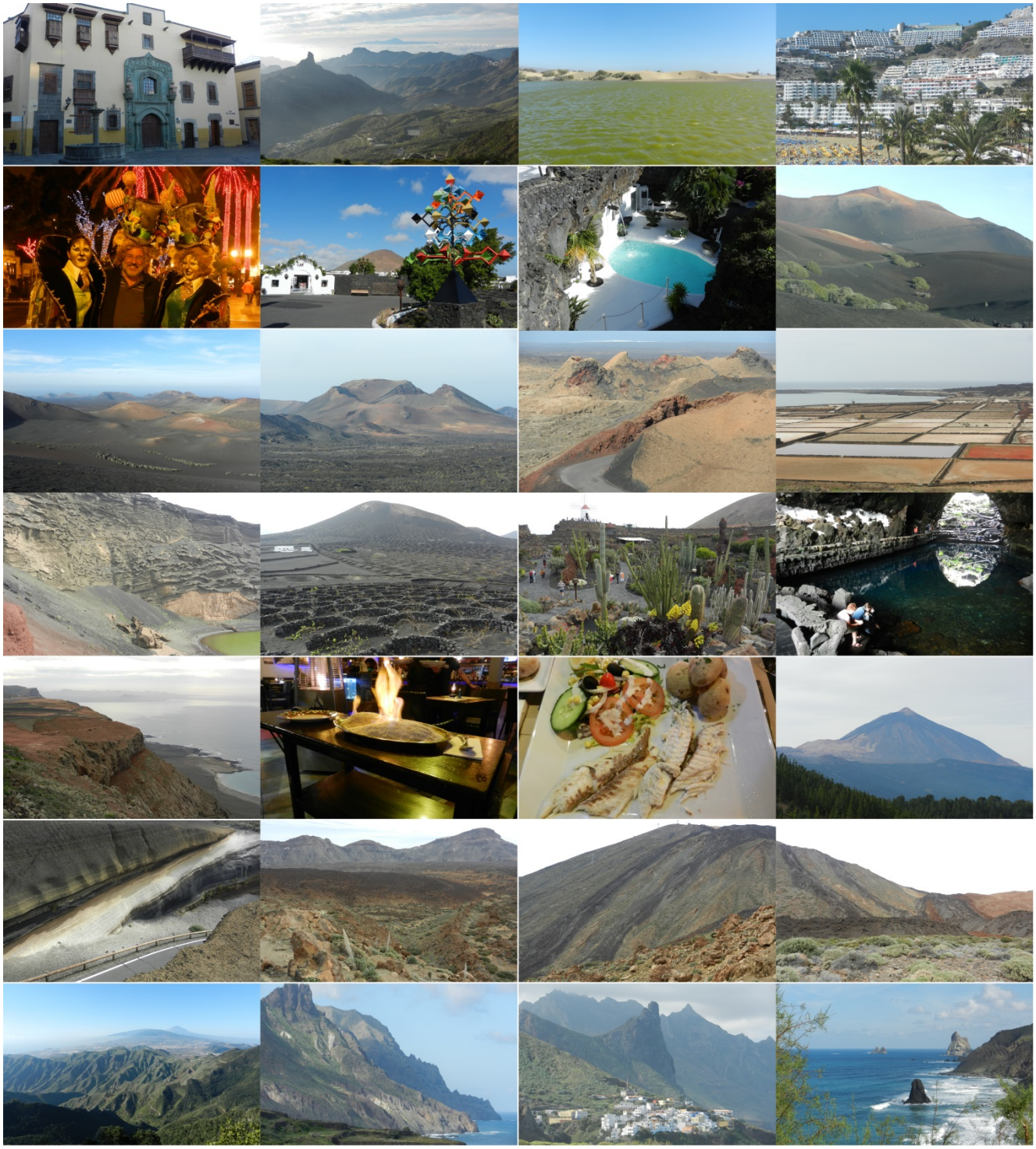
Read the article

Thierry Chopin was a **plenary speaker** and **session chair** at the conference **Challenges in the Environmental Management of Coastal and Marine Areas**, which took place at the **University of Las Palmas de Gran Canaria (ULPGC), Spain**, from January 25 to January 29, 2016.
The objective of this conference was to address challenges in the environmental management of coastal and marine areas located in European outermost regions and overseas countries and territories, taking into account that the sustainable development of a blue growth strategy within these territories requires the maintenance of the quality, richness and diversity of coastal areas while supplying new resources to the populations living in these areas.

The conference was wonderfully organized by **Ricardo Haroun** (ULPGC) and **Gercende Courtois de Viçose** (scientific manager of the ECOAQUA project), who did an excellent job at putting the scientific programme together and delivering it in a very impressive friendly, cultural and gastronomic atmosphere. The conference was also in collaboration with the International Union for Conservation of Nature (IUCN), represented by **François Simard**.
Some of the highlights of the conference can be found here. The conference was divided into 5 sessions over 3 days (integrated management of coastal and marine areas; structure and function of coastal and marine ecosystems; responsible use of coastal and marine resources; effects of global change in coastal and marine ecosystems; and ecosystem conservation and aquaculture). **Thierry Chopin** was the plenary speaker for the first session and gave a presentation entitled **Including aquaculture in the management of coastal and marine areas through the development of integrated multi-trophic aquaculture**. There were also workshops each afternoon, which allowed for some very interesting and spirited discussions (role of aquaculture in marine conservation strategies; threatened marine species: the case of *Cymodocea nodosa* in the Canary Islands; artisanal fisheries in outermost regions and overseas countries and territories).
On the last day, there was a combined closing ceremony/press conference at the impressive ULPGC Parque Cientifico Technológico Marino in Taliarte (just outside of Las Palmas). The main outputs and recommendations from the conference and workshops were presented to the audience, with the President of the Government of the Canary Islands, **Fernando Clavijo**, the Rector of ULPGC, **José Regidor**, and the Minister of Economy, Industry, Commerce and Knowledge, **Pedro Ortega**, in attendance. A Conference Statement was officially adopted. The text of the statement can be found here in its English, French, Portuguese and Spanish versions.
The section regarding aquaculture and conservation reads as follows:
"Synergies between aquaculture and marine conservation activities should be developed. Well-planed and well-dimensioned aquaculture should be used for supporting local communities in, or near, Marine Protected Areas.
Fisheries management and aquaculture sustainable development should be addressed jointly in order to understand how aquaculture could alleviate the pressure on wild stock and reduce negative fisheries impacts such as by-catch and habitat destruction.
Integrated multi-trophic aquaculture (IMTA) should be promoted for its inherent economic benefits from crop diversification, its environmental benefits by contributing to nutrient recapturing and bio-conversion, the ecosystem services it provides, and its contribution to increasing the resilience and the societal acceptability of the aquaculture industry.
Marine regulations adapted to the unique island environmental conditions, as well as to the new technological advances, are urgently required to achieve these objectives. Long-term marine spatial planning tools, along with simplified, flexible and enabling licensing procedures are necessary to underpin a balanced economic development of the diverse activities undertaken by a growing number of stakeholders.
New aquaculture techniques, specific for some marine species, should be considered as tools for the recovery of threatened species, as well as powerful restocking techniques in island systems.
In addition, circular economy principles should be promoted to increase the recovery of waste materials and by-products. Aquaculture and aquaponic practices should be promoted as new innovative approaches creating new products and enabling the creation of biotechnology-related jobs."
The conference was well-covered by the press, with 3 newspaper articles, 2 of which emphasizing the need to develop IMTA.

Read the articles:
- "La buena gestión del mar pasa por la acuicultura multitrófica" by Marta Ramos, in *Canarias 7*, on January 27, 2016.
- "Los expertos solicitan licencia para implantar los policultivos en acuicultura" by María Jesús Hernández, in *La Provincia*, on January 30, 2016.
- "Los expertos piden cambiar la ley para el cultivo sostenible del mar" by Marta Ramos, in *Canarias 7*, on January 30, 2016.

After the conference, Kathy and Thierry Chopin took a week of vacation to explore 3 of the islands of this amazing volcanic archipelago: Gran Canaria, Lanzarote and Tenerife. Each of them has its own character and has found different solutions to deal with the enormous flow of tourism they have to absorb year round. The local population remains most friendly and Canarian food and wines are most delectable.



The **World Aquaculture Society** 2016 conference **"All in for Aquaculture"** was held in **Las Vegas**, USA, February 22-26. **Nine members of CIMTAN** (3 investigators and 6 graduate students) participated in the **"IMTA and Integrated Aquaculture"** session, which included a total of 15 presentations and was followed by a discussion period associated with the Galway Statement on Atlantic Ocean Cooperation (agreement between Europe, Canada and the USA). Another full day and well-attended IMTA session!

The 9 CIMTAN presenters gave a nice representation of some of the achievements in the 3 domains of the network (environmental system performance and species interactions, system design and engineering, and economic analyses and social implications), as it enters its last year of existence:

- **Thierry Chopin** gave a presentation entitled **The Canadian Integrated Multi-Trophic Aquaculture Network (CIMTAN): 2010-2016 – What have we learned?**
- **Shawn Robinson** gave a presentation entitled **Evaluation of the various organic niches in integrated multi-trophic aquaculture (IMTA) from the Canadian east coast**.
- **Bruce MacDonald** gave a presentation entitled **Assessing the suitability of suspension- and deposit-feeding sea cucumbers as extractors of particles in integrated multi-trophic aquaculture (IMTA)**.
- **Angela Fortune** gave a presentation entitled **Integrated multi-trophic aquaculture (IMTA) with the California sea cucumber *Parastichopus californicus*: utilizing animal behaviour and cage design to optimize IMTA system efficiency**.
- **Stacy Murray** gave a presentation entitled **Freshwater integrated multi-trophic aquaculture (FIMTA): developing aquaponics for cold temperate commercial Atlantic salmon *Salmo salar* hatchery systems and investigating the use of IMTA kelp biochar as a plant substrate**.
- **Adam Turner** gave a presentation entitled **Experimental investigation of Canadian fish farm hydrodynamic wake properties and its implication for integrated multi-trophic aquaculture (IMTA)**.
- **Taryn Minch** gave a presentation entitled **High resolution measures of current flows around salmon cages to guide the placement of extractive species for integrated multi-trophic aquaculture**.
- **Hossein Ayouqi** gave a presentation entitled **Economics of integrated multi-trophic aquaculture adoption in Canada: an overview**.
- **Erin Latham** gave a presentation entitled **Making linkages: exploring the future of aquaculture and the potential of integrated multi-trophic aquaculture (IMTA) in British Columbia**.

Karen Jensen, **Muki Shpigel**, **Andrew Suhrbier**, **John Scarpa**, **Graham Mair** and **Ricardo Radulovich** gave presentations on their IMTA projects in the USA, Israel, Australia and Costa Rica.

There were also a few other IMTA presentations in other sessions, in particular the **"Macroalgal Exploitation & Aquaculture"**, **"Aquaponics"**, **"*Macrobrachium*"** and **"Partitioned and Intensive Aquaculture Systems"** sessions.


Rick Moonen and Thierry Chopin (photo credit: Jessica Grimaldo).

Rick Moonen, the celebrated chef of RM Seafood, located at the **Mandalay Bay Resort and Casino** in Las Vegas, gave a lively presentation entitled **The role of serving sustainably sourced seafood in building acceptance of aquaculture products** in the **"Building Social Acceptance through Innovative Communication"** session. Rick, who remembers Thierry Chopin and his IMTA dance at the **Monterey Bay Aquarium Cooking for Solutions** conference in May 2010, gave a resounding endorsement of IMTA: "Integrated Multi-Trophic Aquaculture… a mouth full for a Chef, but a brilliant idea, guys, brilliant!".

The tale of two energies in Sin City

Bob McDonald, the host of **CBC Radio**'s award-winning weekly science program **Quirks & Quarks** (Thierry Chopin was on it in June 2010), recently wrote an article **"Cashing in the energy chips in Las Vegas"**.

Indeed, Las Vegas is an outrageous debauchery of lights and power consumption and waste! The electricity bills are so enormous that several casinos and hotels have installed some of the largest rooftop solar arrays in the USA to harvest this free, year round, energy, which is so abundant in this artificial oasis in the middle of the Nevada desert.

But the local monopoly power utility, NV Energy, based on the exploitation of coal and natural gas stations, is not supportive of this move! It wants its largest consumers, the casinos, to pay multimillion-dollar "exit fees" to leave the utility or local homeowners will be charged higher fees. Moreover, it has also reduced paybacks to those who own solar panels and are feeding excess energy into the grid.

This has effectively squashed any incentive to go solar in Las Vegas, where it would make so much sense to embrace this innovative renewable energy technology. Resistance to change by an industry that did not take the turn at the right time, now feeling threatened, operating with out-dated technology, not interested in money saving and sound environmental practices for the benefit of society, and using its remaining corporate influence and political lobbying … a déjà vu in several other sectors!

How can we embrace new technologies and the emergence of new industries, requiring new skills, while, at the same time, allowing for a smooth transition/reconversion for out-dated industries and their work force fearing unemployment?
How can incentives, that will trigger regulatory, governance and attitudinal changes, be put in place?
Thierry Chopin had two ductless heat pumps installed in his house in January; he is starting to save money and a CAD $1,000.00 discount from NB Power was part of the decision to move to a more friendly approach to domestic heating.

Amazing parallel with the car industry… Would it not be more important to be an energy company, instead of just an oil company? What is important is that people continue to fill up at your stations or that you remain their supplier of energy in whatever form! Some companies are demonstrating this forward-thinking approach. Air Liquide is embracing the hydrogen economy. Toyota is a big player in the transition from internal combustion engine cars (ICEC) to battery electric cars (BEC) or hydrogen fuel cell cars (HFCC).
This transition will require science advances, public relations (PR) and government relations (GR). Policies and incentives/subsidies will be needed to facilitate changes. The automobile industry has had many of them to induce the modification of equipment or reinforce/enforce environmental efficiency improvements.
However, Toyota is also realistic and pragmatic. The first Prius was sold in 1997 and it remains a small fraction of the market. Toyota predicts that BEC and HFCC will finally become predominant by 2050. The ICEC are "legacy cars", with companies wanting their returns on investments before moving to the next era.
Now, let's take all of the above and adapt it to make another parallel, this time with the situation in the aquaculture sector. Moving from traditional monoculture practices to more innovative ones such as IMTA? Changing the regulatory and policy framework? Introducing incentives/subsidies, such as nutrient trading credits, by recognizing the ecosystem services of extractive aquaculture? There are

some amazing similarities!
All that will take time to develop and implement; science and society need time to think and evolve. We should realize that we are still in the infancy of IMTA. If Toyota, with as common a product as a car and a multi-billion market, views 2050 as the new horizon, why are we so impatient that IMTA has not yet penetrated more of the aquaculture industry after 10-15 years of research and development? We also need to be realistic and pragmatic: IMTA will not happen overnight, especially in the western world.
One thing is sure: the vision is clear at Toyota, and the means are in place to achieve the goals. Will we have the same vision, willpower and tenacity in the aquaculture sector? That is maybe where the similarities stop.

Angela Fortune learning how to walk on the oyster rafts at Effingham Oyster Ltd. farm in Barkley Sound, on the west coast of Vancouver Island, where juvenile sea cucumbers, *Parastichopus californicus*, are suspended in six different cage designs below five of the oyster rafts (photo credit: Colleen Haddad and Hailey Davies).

Angela Fortune obtained her Bachelor of Science in Biology from Simon Fraser University in 2013. She first became captivated by IMTA during a field school semester at the Bamfield Marine Science Centre, where she completed a research project on kelp growth rates, with IMTA in mind. The promising potential of IMTA to reduce negative environmental impacts of aquaculture while addressing economic and social considerations is what makes Angela so passionate about her Master's thesis project with CIMTAN. Angela is in the second year of her MSc, co-supervised by **Chris Pearce**, a Research Scientist at the Pacific Biological Station in Nanaimo, British Columbia, and **Stephen Cross**, an Associate Professor at the University of Victoria. Her CIMTAN thesis project is investigating sea cucumber (*Parastichopus californicus*) cage design in order to optimize the benthic extraction of nutrients within an IMTA system. Because of the sea cucumber's morphology and behaviour, containment can be difficult without reducing nutrient transfer and overall IMTA efficiency. Mesh size small enough to contain the sea cucumbers would reduce the amount of incoming nutrients from the above IMTA component, reducing the IMTA system's overall efficiency while also causing maintenance issues for farmers. Angela is attempting to utilize animal behaviour and habitat preference to optimize the retention of juvenile sea cucumbers within trays, without hindering nutrient transfer to this benthic IMTA component. Juvenile sea cucumbers exhibit cryptic behaviour and a preference for hard substrates with wild juvenile *P. californicus* found in high abundance on and below oyster farm gear. These behaviours were carefully considered when developing suspended cage designs. Eight modified high-flow oyster tray designs were initially tested in the laboratory, with six designs subsequently chosen for field trials at **Effingham Oysters Ltd.**, a Pacific oyster (*Crassostrea gigas*) farm, on the west coast of Vancouver Island. Data analysis is ongoing, though preliminary results indicate a clear trade-off between nutrient capture ability and containment among the sea cucumber cage types. Angela hopes to continue working in the aquaculture sector and towards sustainable aquaculture practices and solutions.

When Angela is not working on her thesis, she can be found kayaking around Nanaimo harbour, exploring other areas of Vancouver Island, or at home binge-watching Netflix while working on art projects.

CIMTAN member quote of the month: "Sea cucumbers are fascinating animals to study with their pentaradial symmetry, locomotion via their water vascular system and hundreds of tiny tube feet, an un-centralized nervous system, an ability to eviscerate organs, and their soft bodies which can quite dramatically change shape and size. Although, it's these interesting characteristics that make sea cucumbers difficult to contain in a traditional aquaculture setting. The solution to this containment issue requires thinking outside the box and within the ecosystem-based management approach to IMTA" (*CIMTAN MSc candidate Angela Fortune*).

California sea cucumber, *Parastichopus californicus*, hiding in a Pacific oyster, *Crassostrea gigas*, shell at Effingham Oyster Ltd. farm in Barkley Sound, on the west coast of Vancouver Island (photo credit: Angela Fortune).

If what some colleagues have been kind enough to call the "Chopin effect" (an inverse relationship between phosphorus availability in seawater and the content of carrageenans in some tropical and temperate red seaweeds) was demonstrated in the 1990's, by reference to the so-called "Neish effect" describing a similar effect with nitrogen nutrition demonstrated in the 1970's, you never know what the music of Frédéric Chopin will trigger! That's the other "Chopin effect"!