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Marine Aquaculture and the Environment

A meeting for Stakeholders in the Northeast

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Aquaculture from a different angle: the seaweed perspective, and the rationale for promoting integrated aquaculture

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Aquaculture, especially in the Western World, is very often conducted in a monotypic manner without employing a balanced approach for long-term sustainability, which would take into consideration the assimilative capacity of the ecosystem. To develop innovative, effective and responsible practices – maintaining the health of coastal waters, and, consequently, of the cultured organisms – fed aquaculture types (*e.g.* finfish, shrimp) and organic or inorganic extractive aquaculture types (*e.g.* shellfish or seaweed) need to be integrated to avoid pronounced shifts in coastal processes. Most impact studies on aquaculture operations typically have focused on organic matter/sludge deposition. However, the inorganic output of aquaculture is presently emerging as a pressing issue as nutrification of coastal waters is a worldwide phenomenon, which has not spared the Bay of Fundy (Chopin et al. in press). Conversion, not dilution, is the solution so that the "wastes" of one resource user become a resource (fertilizers) for the others. It can frequently be heard that the development of "alternative" species will reduce some of the aquaculture impacts. Unfortunately, too often "alternative species" in the minds of a lot of people means "alternative species… of fish". Even though introducing another species of fish may add up economically in the short term, rarely does it balance energetically and environmentally in the long term. It is still fed aquaculture, with extra, unconsumed, pellets and unidirectional metabolic excretion. For a balanced ecosystem approach what is needed is a diversity of co-cultured organisms, performing different processes throughout the day and seasonally, and an estimate of the proportionate biomass of each so that their metabolic processes compensate each other.

For example, the aquaculture industry in New Brunswick is geographically highly concentrated. Contrary to common belief, even in regions of exceptional tidal and apparent "flushing" regimes like the Bay of Fundy, water mixing and transport may be limited and water residency time can be locally prolonged (Page 2001). Hence, nutrient bio-availability remains significant in some areas for a relatively long period of time in terms of assimilative processes.

Preliminary data to develop a nutrient budget for the Bay of Fundy, show that aquaculture operations in the Quoddy Region contribute 30-40 times more phosphorus and nitrogen than sewage treatment facilities. The dominant macro-alga in the region, *Ascophyllum nodosum* (rockweed), develops reproductive structures which each spring reach 20-25 % of the plants' dry weight before being shedded in May/June, hence contributing 10 times more phosphorus and nitrogen to the Bay than sewage treatment facilities. The impacts of agricultural/industrial runoffs, urban/rural effluents and precipitations remain to be appropriately quantified. If, indeed, the finfish aquaculture industry should not be the only one to be singled out because it is the "new kid on the coastal block", as a relatively new contributor to the overall nutrification of coastal waters, it should not be exempt from developing innovative practices that ensure the remediation of the consequences of its activities.

This is precisely when one of the contributions of seaweeds to coastal ecosystems must be recognized and used. Unfortunately, it is striking to realize that – especially in the marine biology community in the Western World, historically dominated by zoologists who have been "kingdomly incorrect" for decades – the fundamental role and contribution of seaweeds in coastal processes have frequently been either ignored or misunderstood, and that seaweeds are rarely factored into modeling equations of coastal systems. For example, in 1995 China produced more than 4.8 million tons of seaweeds through aquaculture (Hanisak 1998). Such a tremendous biomass certainly provides a significant "buffer capacity" along the Chinese coast in terms of nutrient assimilation and conversion (Fei et al. 1998).

Physiologically, seaweeds can be viewed as renewable biological nutrient scrubbers which take up nutrients in the same way sponges absorb water. However, like any sponge, they can only absorb so many nutrients before they become saturated. This validates the sustainable harvesting of seaweeds (periodic removal of saturated tissues, and therefore of significant amounts of nutrients, to allow the regrowth of new material to continue the scrubbing process) and their cultivation integrated to fed-type operations to provide nutrient bioremediation capability, mutual benefits to the co-cultured organisms, economic diversification by producing another value-added marine crop, and increased profitability per cultivation unit for the aquaculture industry (Chopin et al. 1999a,b). The target should be the development of enough competition for nutrients by cultivation of desirable algal crops to reduce nutrient concentrations in seawater and the biomass of problem species below the threshold of devastating and costly hypertrophic events such as green tides (extensive blooms of macro-algae such as *Enteromorpha*, *Ulva* and *Cladophora*) and red tides of harmful micro-algal blooms (Merrill, 1996).

These concepts are the basis of our on-going projects in the Maritime Provinces, Canada, and in New England, USA, with the red alga *Porphyra* integrated with salmon (*Salmo salar*) culture at sea, and with summer flounder (*Paralichthys dentatus*) culture on land. *Porphyra*, commonly referred to as nori, is the well-known wrapper for sushi in Asian cuisine, but is also used in several other biotechnological applications (Yarish et al. 1998). For rapid growth and appropriate marketable pigmentation, *Porphyra* requires constant availability of nutrients, especially in the summer when temperate waters are generally nutrient depleted. Cultivation of nori in the proximity of salmon cages allows the alleviation of this summer nutrient depletion by using the constant nutrient supply of fish farms, which is then valued and managed. This represents a clear case of mutual benefits for the co-cultured organisms when meaningful developments in integrated coastal zone management are sought: seaweeds use the nutrients required for their growth, while contributing to water quality improvement around fish for their health enhancement.

We have also been working on estimating the *Porphyra* production in tanks required to remove phosphorus and nitrogen generated by a summer flounder farm on land, operated by Great Bay Aquafarms, Inc., in New Hampshire, USA. A commonly heard myth is to assume that all present aquaculture nutrification impacts will disappear when aquaculture operations move on land, a solution presented by some as the way of the future for the aquaculture industry. It will certainly alleviate the problem of dilution of the nutrient loading in water bodies which become very difficult to monitor and treat. Concentrated effluents from on-land aquaculture operations will remain, however, to be channeled through pipes and be appropriately treated before being re-used (closed systems) or discharged (open systems). At the present time, we are modeling the algal biomass and culture volume that would be necessary to achieve the bioremediation of certain nutrient amounts by considering four key variables: the algal stocking density, the algal nutrient content, the algal growth rate, and the biomass harvesting frequency.

An accrued benefit to operators of this type of aquaculture is the fact that the currently discharged (unassimilated and/or excreted) phosphorus and nitrogen, which represent a loss of money in real terms, will be captured and converted into the production of salable nori and biochemicals, hence generating revenues which will more than compensate the expenses. Additionally, as legislative guidelines/standards/controls on the discharge of inorganic nutrients from aquaculture operations into coastal waters become more stringent, bioremediation via the production of seaweeds will help the fish aquaculture industry avoid non-compliance.

To successfully develop integrated aquaculture systems, much research (R) and development (D) remain to be undertaken, particularly in the areas of:

1) transfer and modification of cultivation technologies to local environments and socio-economics;
2) development of the cultivation of native species of marketable value that will be fast growing at different times of the year and in diverse habitats;
3) site-specific biological, chemical, physical, and socio-economic modeling to define the appropriate proportions between the different co-cultured organisms;
4) development of a regulatory and legislative management framework with enough flexibility to allow experimental and innovative practices at a meaningful pre-industrial scale.

Pivotal for the success of the aquaculture industry in the future will be the wise investment in R&D (not D&R, as we see too often!) to move in new directions to optimize its efficiency through diversification, while maintaining the health of coastal waters. The aquaculture industry is here to stay in our “coastal scape”: it has its place in the global seafood supply and demand, and in the economy of coastal communities. To help ensure its sustainability, however, it needs to responsibly change its too often monotrophic practices by adopting polytrophic ones to become better integrated into a broader coastal management framework.

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