Epilogue: Aquaculture, Innovation and Social Transformation

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Aquaculture, not the Internet, represents the most promising investment opportunity of the 21st Century.
Peter Drucker, Economist and Nobel Laureate

This pioneering volume is about two things: the poignant clashes of views regarding aquaculture, and the underlying question of how we are to make complex choices regarding use of new technologies to produce food for a hungry planet. As the editors put it, "The debate (over aquaculture) is at least emblematic of, if not literally about, the struggle over the place of technology in human life and the life of the planet." The context of this volume's approach to the debate could hardly be better suited to facing this two-layered question: the waning growth of aquaculture in Canada, a global small-player in aquaculture which nonetheless has huge potential to participate in aquaculture. The particular value of this volume lies in the way Culver and Castle have intentionally engineered a clash of cultures as they have asked the very diverse authors of this volume to take up various parts of a provocative question: "Does Canada – the world's largest ocean nation – want to become an 'aquaculture nation'?"

A tangled set of further questions lies beneath the challenge facing Canadians. What can the world learn from Canadian experience in aquaculture? In Canada, aquaculture is a controversial "new" use of aquatic ecosystems, and while the potential for aquaculture is significant, the sector flounders in a context in which political will is often enough to lead to substantial financial backing of innovation in a sector. What can the world tell Canada about how to face the question of whether, and in what way it can it be, a global leader in aquaculture? What would it mean for other countries were Canada to face the social transformation caused by new technology innovation in an industry that competes, and threatens to replace, a capture fishery imbued with history and mythology about traditional practices? Can a new vision arise where innovative aquaculture businesses evolve into modern, 21st century, knowledge-based operations dedicated to pioneering the development of planned, well-integrated, socially acceptable aquaculture systems that have positive multiplier impacts on both natural and social ecosystems?

Aquaculture is nothing new. It arose multiple times in many indigenous societies where coastal population densities of "seafood eating peoples" increased beyond the carrying capacities of natural, aquatic ecosystems to provide for them. There have been many "blue revolutions" throughout history! But modern aquaculture is very different, being technologically complex, and, given a social makeup of a society (urban, rural, rich, poor, etc.) communities can either embrace such dramatic change, and accommodate the necessary social transformations, or reject such change and continue their social, cultural, and economic evolution without aquaculture. One of the fundamental problems of aquaculture development is the lack of understanding and planning for the social/community transformations wrought by aquaculture innovations, and the lack of knowledge on how to govern aquaculture innovations. The divergent and fascinating First Nations perspectives on aquaculture reviewed herein are a case in point, one that has fascinated me for a long time, namely, the evolution of aquaculture in ancient societies, and the use of that traditional knowledge to evolve an alternative path for coastal societies worldwide (Costa-Pierce, 1987, 2002). Yet no matter the sources of the knowledge we use to chart a course for aquaculture – whether traditional knowledge, science, or some blend, well planned, transparent, participatory processes are required; ones that may drag out for longer than decision-makers want, but in the end will lead to some shared visions of more common futures.

In this regard, the nation-state has a particularly difficult time dealing with such long, oftentimes contentious local/regional participatory processes. Aquaculture planning issues are invariably tied to people's visions of their communities, their past, and their ideas of the future of a working waterfront. Welcome the stark contrast in the social/community acceptance of salmon aquaculture in Newfoundland versus British Columbia where different regional visions of the past and the future drive the acceptability of innovations such as aquaculture. Matters become all the more complicated when community identities and aspirations for the future have to interact with decide to use or step away technologies of uncertain merits, often under the pressure of advice from people who are not members of the affected community. Culver and Castle point out that Canadians' favorite public value of consensus works poorly at the nation-state level, and hardly any better within the country's diverse regions. Furthermore, aquaculture innovations are so diverse that no one pathway for coordinating social acceptance with technological innovation is possible. It may be the case that in each instance of technology uptake into the aquaculture industry, active social engagement – a learning community of sorts – needs to be developed to take stock of the wide diversity of aquaculture innovations.

There is an intriguing contrast visible in the difference between global opinion and what authors in this volume represent as an often negative Canadian public opinion of aquaculture. Most global analysts agree that a rapid acceleration of aquaculture - the "blue revolution" - is not only needed, but is a forgone conclusion given global demand for sustainable sources of food protein. In addition, any rigorous comparisons of aquaculture with other food protein production systems reveal that aquaculture is a very efficient mass producer of animal proteins for a crowded, coastal planet, and also has great potential to transform coastal societies. Comparisons against an array of capture fisheries and terrestrial agriculture systems confirm that aquaculture - even as currently practiced (e.g. in its "current state of evolution") is superior in terms of financial and social impacts (profit per ha; social multiplier effects), and energy and production efficiencies.

Aquaculture could mitigate the effects of the disastrous trajectory for terrestrial meat production and the capture fisheries. FAO (2007) estimate that 77% of all global fish stocks are either fully exploited with no room for further expansion; or are overexploited, depleted, or recovering from depletion owing to excess fishing pressure. FAO (2007) project that capture fisheries production from 2004 to 2030 will remain stable at 86-87 million metric tones, while aquaculture will almost double from 45 to 83 MMT during the same time. Much of the pressure to increase aquaculture production is derived from considerations of efficiency. Goodland & Pimental (2000) state, "In the worldwide effort to increase food production, aquaculture merits more attention than raising grain-fed cattle". Production efficiencies of edible mass for aquaculture range from 2.5 to 4.5 kg dry feed/kg edible mass compared with 3.0 to 17.4 for conventional terrestrial animal production systems. Beef cattle require over 10 kg of feed to add 1 kg of edible weight, whereas catfish can add a kg of edible weight with less than 3 kg of feed. By comparison, wild, "capture" fisheries are less efficient from both trophic and energy efficiency perspectives.

Coastal and oceanic ecosystems have trophic efficiencies of 10 to 15%, and mean trophic levels of 3.0 to 5.0 (Ryther, 1967), whereas mean trophic levels in aquaculture systems range from 2.3 to 3.3, with highest aquaculture trophic levels in North America and Europe (Pullin et al., 2001). Pullin et al. (2001) state that "most ocean fish consumed by humans have trophic levels ranging from 3.0 to 4.5 (Pauly et al., 1998); i.e. 0 to 1.5 levels above that of lions". Vernon (2007) completed an anlaysis of salmon ranching versus salmon farming in the north Pacific Ocean, and concluded that salmon ranching as practiced currently in British Columbia, Alaska, and Japan, introduces 250 times more smolts and consumes 70 times more feed to produce less than 10 times the volume of marketable salmon than salmon farms. To produce 1 kcal of catfish protein about 34 kcal of fossil fuel energy is required; lobster and shrimp capture fisheries use more than 5 times this amount of energy. Energy costs for even the most intensive salmon cages are three times less than lobster and shrimp fishing, and are comparable to beef production in feedlots.

In light of the superior efficiency of aquaculture, the sometimes negative public view of aquaculture in Canada appears for a moment to be a strange anomaly – until we bring to mind again the observation of Culver and Castle that the debate over aquaculture is simultaneously a debate about the place of technology on our coasts and in our lives. If aquaculture is to be a vital part of the knowledge-based, innovation economy for coastal societies in Canada, and worldwide, aquaculture must be better integrated into social life. Aquaculture is technology intensive and rapidly evolving, and so those who wish to use it must keep follow the pace of change. What is required is an entirely new view of what the blue revolution is not, to clear away false expectations and misconceptions, but also what it can be: a new pathway to sustainable development for aquaculture – an alternative path to wasteful food production techniques – and the birth of new institutions to help direct and support the massive social transformation of some coastal societies dealing with new aquaculture proposals. It is crucial to remember when thinking of coastal societies that like the rest of us, most are not keen to become historic theme parks where fishermen's wharves are devoid of fishermen. Coastal societies are typically intent on both preserving their glorious past, and securing the future of their working waterfront.

The Green Revolution is Not a Model for the Blue One

In my opinion, aquaculture's future growth as projected by FAO will not occur in Canada or elsewhere unless aquaculture developers choose a route other than the failed "green" revolution with its adverse environmental, ecological, community, social, and ethical impacts.

The Green Revolution raised agricultural yields, especially in India, but did not strive to involve agribusiness and multinational food corporations with communities, farmers, or local governments to build, invest in, and nurture change in local institutions, communities and cultures. As a result, accelerated production did not alleviate poverty or eliminate hunger, and production gains damaged the environment. Numerous multidisciplinary studies, especially in Mexico and India, have shown that the Green Revolution's expensive seed, fertilizer, pesticide and irrigation "packages" favored a minority of economically-privileged farmers (Rosset et al., 2006). Environmentally, the green revolution produced a well-documented litany of "externalities": accelerated pollution of rivers and water tables, widespread soil degradation, losses of biodiversity, and occupational pesticide poisonings. In India, the Green Revolution's "technology packages" required irrigation; so the government subsidized the digging of tens of thousands of wells which pumped many water tables dry, forcing vast areas to return to traditional, dryland farming systems. Most of India's grains were exported, so national elites profited mightily. The local, hydrological result of the Green Revolution's technology packages was "the sacrifice of India's ancient aquifers to the international grain trade" (Rosset et al., 2006).

My Crystal Ball is Blue…If Viewed Through the Right Lens

Aquaculture developments are rarely planned as social transformations. Modern aquaculture is still new to our policy institutions, governments and universities. Aquaculture is rarely considered as a part of social design and transformation; and is rarely thought of as an exciting new field of multidisciplinary scholarship having its own merits in the context of innovation, cultural evolution, knowledge systems, knowledge acquisition and management. Discussion of advances in the field of aquaculture is similarly at an early stage of development, largely dominated by technological and natural science findings while the relatively few social researchers interested in aquaculture struggle to keep up with the sheer volume of the science and its interaction with social issues. Aquaculture developments today are commonly considered as "industrial primary production". Metrics of "success" rarely include anything other an exports of tons of fish produced. In the face of what is presented as "success" we are now facing concerns that can no longer be ignored: charges that aquaculture's current mode of industrial expansion is leading to a failed pathway of "boom and bust" cycles. Such cycles have plagued the development of shrimp, tilapia, and salmon aquaculture worldwide. Why have these occurred?

The relative narrowness of aquaculture research is unfortunately paralleled in many governments by equally narrow expertise and responsibility for aquaculture. Aquaculture impacts many sectors of society, but aquaculture is rarely considered comprehensively by government. Decision-making about its future is currently made principally by the minds of a few specialists in governments who oftentimes are untrained in aquaculture; these power-brokers are routinely ensconced in the bowels of government agriculture or fisheries departments. As a result, "boom times" get much attention by important people; "bust times" are those where a few specialists are left to clean up the mess.

Inadequate training and knowledge are often at the root of poor planning and exaggerated claims regarding the merits of aquaculture. Too often, aquaculture comes into coastal communities with great promises of innovation amid projections of positive impacts on the local economy. Aquaculture's extraordinary potential for generating large scale multiplier impacts are rarely achieved, however, or if they are, they are achieved as poorly planned afterthoughts, not as well planned, collaborative developments that have at the outset included a broad range of local stakeholders, policy-makers and allied supply-side businesses. According to Dicks et al. (1996), aquaculture production in the USA accounted for only 16,500 jobs and just 8% of the income. Aquaculture goods and services (feeds, fertilizers, processing, transport, equipment, supplies, etc.) accounted for 92% of the income and about 165,500 jobs.

Multidisciplinary Aquaculture Social Science Needs

In my view, we have yet to take two crucial steps needed to develop the alternative path for aquaculture development as social transformation: (1) Industry commitment to implementation of an ecosystem approach to aquaculture (EAA); (2) Development of alternative institutions that would team government, universities and industry, whose mission would be to multidisciplinary learning, social transformation, and the aquaculture "innovation portfolio". University involvement is essential as a "keeper of the flame" since neither government nor industry can effectively play the role of an honest broker. What is required is a neutral convener and purveyor who can help lead the integration of an EAA with institutions committed to social change who pay close attention to market and societal transformations (such as progress towards: internationalization and multiculturalism, sustainability, bioregionalism, carbon footprints/trading/food miles). Societal transformations need time and stable funding bases to foster unique partnerships. Such type of leadership is fully underway in agriculture, and could be an important model for aquaculture. I hope and anticipate that this seminal volume will, in and of itself, go a long way towards developing further a cadre of multidisciplinary scholars in aquaculture; and additionally stimulate formation of new institutions committed to developing cadres of science-policy-innovation experts.

An Ecosystem Approach to Aquaculture (Natural and Social Ecology)

Implementing an ecosystem approach to aquaculture (EAA) is a major global trend (FAO, 2007). At an FAO Workshop on EAA in Mallorca, Spain in 2007, an EAA was defined as "a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems".

Soto (2007) has defined an ecosystem approach, like any systems approach to management, as accounting for a complete range of stakeholders, spheres of influences and other interlinked processes. Applying an ecosystem-based approach must involve physical, ecological and social systems in the planning for community development, while also taking into account stakeholders in the wider social, economic and environmental contexts of aquaculture. Soto (2007) developed the following three principles and key issues of an EAA at the different scales:

PRINCIPLE 1: Aquaculture should be developed in the context of ecosystem functions and services (including biodiversity) with no degradation of these beyond their resilience capacity. The key issue here is to define and estimate resilience capacity or the limits to "acceptable environmental change". A range of terms has been used to characterize the appropriate limits, including “environmental carrying capacity”, “environmental capacity”, “limits to ecosystem function”, “ecosystem health”, “ecosystem integrity”, “fully functioning ecosystems”, all of which are subject to a specific social, cultural, and political context.

PRINCIPLE 2: Aquaculture should improve human-well being and equity for key stakeholders. This principle ensures that aquaculture provides equal opportunities for development, and that the benefits from aquaculture are properly shared while not resulting in detriment to society, especially the poor. Both food security and safety are key components of societal well-being.

PRINCIPLE 3: Aquaculture should be developed in the context of other sectors, policies and goals. This principle recognizes the important interactions between aquaculture and the larger ecosystem, in particular, the influence of surrounding natural and social environments on aquaculture. Aquaculture does not take place in isolation from other activities, and, in is usually not the only human activity impacting water bodies that are otherwise more severely affected by agriculture, industrial activities, and human wastes. This principle acknowledges the opportunity to couple aquaculture activities with other production sectors in order to promote material and energy recycling. Aquaculture sites are not only economic engines of primary production that work so long as they comply with local regulations. Aquaculture sites can also be sources of innovation and pride if they can be designed, community-based, farming ecosystems. Regular reviews of progress towards an ecosystems approach to aquaculture are necessary to inspire planners and environmental decision-makers (at many societal scales - national, regional, local) to use new, innovative approaches. Sophisticated site planning of aquaculture can occur so that farms “fit with nature” and do not displace or disrupt invaluable aquatic ecosystems or conservation areas, and also contribute to the local economy and society.

In as much as EAA calls for technological solutions that fit aquaculture technology into ecological constraints, it also requires social change for the acceptance and wise use of innovations. All too often, aquaculture comes into coastal communities so poorly planned that its extraordinary potential for generating large scale multiplier impacts is recognized only as an afterthought and by accident, not as the result of well-planned, collaborative developments involving from the outset a broad range of policy-makers and allied supply-side businesses. Authors of this book make a strong case that aquaculture’s future in Canada, as an example nation, is tied to this “innovation portfolio.” Aquaculture’s future is much more than a simple technological exercise—it is an exercise in multidisciplinary, multi-institutional, environmental scholarship—requiring aquaculture developers to devise planned, systems approaches that include communities and their traditional knowledge systems to insure their “coastal futures”.

Felt in this volume points out “it all depends on the lens, b’y”. Indeed, at the community level, science facts may mean little to policy decisions; communities can find it difficult to separate societal values from science. The precise meaning ascribed to key science and ecosystem terms is more often than not a battle over science: ultimately, it is a debate over which policy option is selected. The debate over what might appear to be semantic nuances is really a surrogate debate over values and policy preferences. Words such as "degraded", "damaged", healthy", and the relative importance of natural versus altered environmental conditions are calibrated by societal values and preferences, not only science. One person's "damaged" ecosystem is another’s "improved" one. A "healthy" ecosystem can be either a swamp infested with mosquitoes, or an intensively managed fish pond.

Ryan et al. in this volume state that "The pro/anti approach is frustrating for resource managers to have to wade through rhetoric instead of spending precious resources on progressive innovation". Such debates are rarely sophisticated enough, however, since the art and science of "the process" – of the proper design to air completely opposing views and bring them together (Martin, 2007) – is rarely considered important enough to invest in. For example, we routinely review the "environmental impacts of aquaculture", but fail to examine fully the environmental benefits of aquaculture (Rensel, 2007), or the notion of aquaculture ecosystems (Costa-Pierce, 2003), similar to the popular ideas of "agroecosystems" (Gliessman, 2006). As a more provocative example, there are reports of land-based salmon aquaculture being not economically feasible but there are few visionary, multidisciplinary, social-ecological, economic feasibility studies on how it to make it viable. Scientists also say that other industries release more nitrogen to the BC marine environment than aquaculture (Cubitt et al., this volume), but we never discuss these other industries, and their plans for the future. Continuing on, we know that salmon escapees of non-indigenous salmon species seed the marine environment with an exotic species that Mother Nature never intended to be there, but we rarely discuss how the use of indigenous salmon species in aquaculture may be a higher risk to the genetic integrity of native salmon (Fleming, 2005). Plus, we know that billions of salmon smolts are seeded into the Pacific Ocean from salmon hatcheries - can these produce more detrimental food chain impacts than aquaculture (Vernon, 2007)? All of these examples support the argument of Antle and Wagenet (1995) who emphasized, over a decade ago, that systematic frameworks are required, so that economic data and data from other, interacting disciplines can be collected and integrated using common units of measurement.

Aquaculture knowledge is fluid, international and innovation is at its heart. The fascinating topic of "intangible assets" in this book reminded me of how poorly we plan for innovations in aquaculture. Much of aquaculture's true worth is not in fish or clams; it is in the intellectual capital that moves freely across borders. Culver calls these "national and supra-national systems of innovation," and applied aquaculture scientists/outreach specialists know exactly what he is talking about. Western scientists have lived for years in the major aquaculture growth regions of the world and have brought with them not only their brains, but also their attitudes, habits, families, etc. Many stayed, "went bush", and became essential parts of the cultural evolution of aquaculture in those societies. "Outsiders" became "insiders" and grew to know as much (or more) than many native-born about the local, cultural development of aquaculture, aquaculture families and communities in those societies.

<u>Institution-Building</u>

Alternative paths must be nurtured by alternative institutions capable of translating research into action and governance of action. Fostering an alternative path to aquaculture development will require the design and development of alternative institutions committed to developing the "innovation portfolio" and charting the future development of socially and ecologically responsible aquaculture industries that are well integrated into coastal societies. Globally, we do not have these institutions yet, and where they made baby steps forward, they have ultimately failed. The causes of institutional failure in aquaculture need further investigation before we can say with certainty what went wrong. Yet that need should not stop us from trying to be clearer about the conditions for success. Sustainable aquaculture needs well-designed, facilitative, collaborative (industry, government, universities, NGOs) institutions working with adequate funding, using multidisciplinary approaches to setting research and outreach priorities, and assessing research and outreach impacts. This 'triangulated' approach to the problems, and some of the pitfalls, is usefully displayed in this book's model of contested exchange between interested and affected stakeholders in aquaculture.

There are several lessons to be drawn from this experiment with a model of contested exchange, but perhaps one of the most important is this: As aquaculture continues to expand, the role of research and development will be key and will perhaps increase, contrary to the 'once and done' attitudes which sometimes plague bureaucrats looking for single-step innovation which will then provide a durable socio-economic base for some society. Globally, aquaculture development has been hampered by three factors relating to the fundamental requirements of research and development: insufficient funds, lack of core research staff, and weak research infrastructure (FAO, 2007). An increase in the quantity and quality of human resources focusing on aquaculture innovation is essential in the search for new aquaculture opportunities. Successful human resources development will trigger the development of more efficient aquaculture-related technology, legislation, and management (FAO, 2007).

The International Agriculture Research Centers allied under the CGIAR network (Consultative Groups in International Agriculture Research) are good models to consider, since these institutions develop research priorities that are driven not only by science needs but also economic efficiency, equity, internationality and sustainability (Kelley et al., 1995). Such characteristics are very important to support the development of an ecosystem approach to aquaculture, especially in a time of intense competition for scarce funds. It is important when laying out research priorities that anticipated benefits flowing from additional investments as well as the opportunity costs are made explicit. Kelley et al. (1995) state how ICRISAT (International Crops Research for the Semi Arid Tropics) provided clear criteria for establishing choices among competing research activities, that were analytically rigorous, drew on scientists' empirical and intuitive knowledge base, and were transparent and interactive. ICRISAT developed themes for collaborative, multidisciplinary research that were impact-oriented, and projected clear milestones against which progress was measured and evaluated. In the US, the Land Grant and Sea Grant College Programs is another model, not only for aquaculture, but also for many diverse aquatic/ocean/coastal disciplines with which it interacts. Sea Grant connects universities to industry and government in a collaborative manner to address integrated, multidisciplinary, multi-stakeholder problems; and is a proven commodity; but also is vastly underfunded (OSB/NRC, 1994).

Collaborative research designs are needed to meet the standards of good science while also satisfying the standards of accountability and policy relevance. As scientists become involved in the priority setting process, they become aware of the ways that their research can contribute to the mission of publicly funded research. Proper valuation of the economic, environmental, and human health impacts of aquaculture production systems is essential for priority setting and impact assessment; multidisciplinary collaboration is also a critical element of the valuation stage of impact assessment.

The coastal zone management (CZM) and site selection chapters by Lane *et al*., Smith and Chopin emphasize the many aspects of this practical need for proper valuation. Smith calls CZM "a tidy process for an untidy reality". Much discussion over the impacts of aquaculture is based on its siting, and any process that determines siting is, by definition, multi-issue, multi-stakeholder, multi-institutional, and multi-jurisdictional. Smith questions if a multi-criteria approach could ever meet the needs of aquaculture when it involves multiple stakeholders, each of whom have different concepts about what counts as meaningful data, and how the sites current and future use should be valued. Chopin (2004), the pioneer of the Integrated Multi-trophic Aquaculture concept where disparate aquaculture systems are integrated into a designed ecosystem, has brought great attention to this as an alternative model of aquaculture development which could include recreational, tourism, and other stakeholders. Chopin's view of the complementarity of uses and the importance of scientific validation of that complementarity resonates with a future of aquaculture as a vital part of coastal communities that are proud of its new, exciting, knowledge-based future.

Funding for innovation is always a major issue, but fostering the long-term development of such innovative institutions for aquaculture is impossible on competitive funding alone. Huffman and Just (1994) argue that with respect to the development of agricultural experiment stations at US universities, directed ("formula") funding was more productive than competitive grant funding, and that "heavier administrator involvement…enhanced productivity of applied research where approaches and products were specified in advance." One take home message could be that the demise of AquaNet in Canada leaves a vacuum that cannot be filled with many disconnected, short-term projects.

A larger take home message must, however, return to the two-layered problem with which Culver and Castle began. This volume's authors demonstrated convincingly that it is a serious mistaken to take a one-dimensional view to aquaculture, whether that view sees aquaculture as a tool of regional development, as a threat to ecosystem health, or something else. Aquaculture is itself multi-dimensional and making the best use of its potential to contribute to global food security will require far more than the knowledge and skills of natural scientists. Once the multi-dimensional nature of aquaculture is recognized and widely accepted, it is much easier to understand the second layer of this volume's motivating problem. Aquaculture is just one among many complex technologies vying for support in national systems of innovation, and there are lessons to be learned by aquaculture advocates from understanding national systems of innovation, and advocates and operators of those systems can learn about the adequacy of those systems from the way they handle scientifically and socially complex topics such as aquaculture. It's all in the lense, as Felt argues here, and we need to work together – aquaculture advocates, global food security advocates, national science, social science, humanities and other researchers – to develop a point of view we can all live with into the future.

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