The Principles and Practices of Ecological Aquaculture and the Ecosystem Approach to Aquaculture

Barry Antonio Costa-Pierce

"Aquaculture is crucial for supplying the world's food needs for the next 50 years."

— Former United Nations Secretary General Kofi Annan, AquaVision, Stavanger, Norway, June 2012

FIGURE 1. *The Zhejiang Huzhou Mulberry-Silkworm-Fish Pond Aquaculture Ecosystem in China is estimated to be more than 2500 years old, existing to today. It has been designated by the FAO as a "Globally Important Agricultural Heritage System." Photo: www.xinhuanet.com.*

Introduction: Recognizing the Elders

Ecological aquaculture is an alternative model of aquaculture development that uses ecological principles and practices as the paradigm for development of aquaculture systems (Costa-Pierce 2002, 2003, 2013). Ecological aquaculture farming practices celebrated in this field are not new but ancient and widespread, especially in Asia, and part of the human experience over millennia (Beveridge and Little 2002). What is new is the growing global recognition of the importance of these examples. Recovering our common ecological aquaculture history (and her-story, as women played critical roles in all of aquaculture's past) is very important to our common future. Indigenous cultures developed numerous bioengineering and ecological innovations at landscape scales that supported high human population densities in antiquity (Gon and Winter 2019). They are living examples to members of modern societies/communities who have a vision of themselves as continuing to transform towards building ecological societies that incorporate the wisdom of traditional knowledge systems of ecological aquaculture into their futures (Groesbeck *et al*. 2014).

Two examples among the many: FAO (2019) recently designated the mulberry-silk-fishpond and rice-fish aquaculture ecosystems as Globally Important Agricultural Heritage Systems (GIAHS) (Fig. 1). In Australia, devastating bush fires exposed anew an aquaculture short-finned eel farming ecosystem of the Gunditjmara people stretching over 75 km^2 around Lake Condah in south Victoria. The site has been designated a UNESCO World Heritage Site as the Budj Bim Cultural Landscape (Lambert 2014).

Among the first to investigate and promote the "new" field of "ecological aquaculture" as an alternative growth model for aquaculture's future development in regions such as North America, where aquaculture was new (and very alien to the public at large) was McLarney (1976) and MacKay (1983). Bill McLarney was a student of the famed ichthyologist John Bardach at the University of Michigan, who teamed with McLarney and John Ryther, the pioneering aquaculture scientist researching integrated mariculture systems in Woods Hole, Massachusetts, USA, to bring to a wider global audience the history and diversity of aquaculture species and systems, especially Asian integrated aquaculture farming ecosystems. They produced the pioneering textbook, "Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms" (Bardach, Ryther and McLarney 1972).

Bill McLarney was a founder with John and Nancy Todd, Ron Zweig and Earl and Hilde Barnhart (and many others) of the eclectic and pioneering New Alchemy Institute (NAI) in West Falmouth, Massachusetts whose research works in applied ecology during the 1970s-1980s laid the foundation visions of a future ecological society. NAI pioneered much of what today has become "permaculture." The integrated renewable energy food bioshelters they designed and implemented intrigued many, including world leaders such as Canadian Prime Minister Pierre Trudeau (Justin Trudeau's father) who dedicated "The Ark" on Prince Edwards Island. NAI was also among the first to weave into discussions of the social implications such designed ecosystems as "appropriate technologies." These have evolved today into the impacts of technological innovations on "social-ecological systems," an example of which for aquaculture is Johnson *et al*. (2019).

Among the many, famed architect Buckminster Fuller and renowned ecologist Eugene Odum visited NAI and praised their solutions for societies worldwide that they felt were losing their way. Ron Zweig of NAI became the fisheries and aquaculture leader for The World Bank, impacting aquaculture development throughout the world. Bill McLarney later became an environmental leader recognized globally for working with indigenous peoples to help save one of the world's most biodiverse regions, the tropical Atlantic Talamanca ecological systems of Costa Rica. John and Nancy Todd have continued to the present day implementing their ecological designs, pioneering the concept of "living machines"

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and obtaining global recognition for their works (Todd 2006). Rose (2019) wrote in The Guardian, "It's 50 years since the New Alchemy Institute created its 'living machine' — a research project of organic farming, renewable energy and sustainable architecture. Did these ecopioneers design a blueprint for our future?"

The Aquaculture book and NAI captivated the imaginations (and careers) of thousands in the West who knew little of aquaculture, integrated aquaculture systems or Asia, including me, who was newly enrolled in graduate school at the time (and ruining his life) pursuing a traditional path of "science." Realizing my passions were being subsumed by my own ignorance, I dropped out, joined Goddard College in Vermont and developed new versions of the integrated aquaculture-agriculture bioshelters there (Pierce 1980); plus entered into their on-going and free-wheeling discussions of aquaculture in the overall development of Goddard's Institute for Social Ecology (ISE). The eclectic scholar, Murray Bookchin, who wrote of the world's environmental crisis around the same time as Rachael Carson's Silent Spring (Bookchin 1962) and later published the seminal volume of social ecology, "The Ecology of Freedom" (Bookchin 1982), led the ISE. Murray was a powerful voice reminding us of "the social ecology of aquaculture." He influenced not only me but also the Dean of Goddard's Resident Undergraduate Program, Jim Nolfi, who wrote the first essay I ever saw with this specific title. We visited, hosted and studied closely the leadership visions and real, on-the-ground examples of ecological design (Todd 2006), especially the works of the NAI's lead aquaculture ecologist, Ron Zweig, who was implementing solar aquaculture, bioshelters and permaculture gardens incorporating aquaculture. All of these I continue today as my lifelong passion.

After joining the World Mariculture Society, I met allies from throughout the world with the same passions but with a lot more experience globally. In 1983, I teamed with Ken MacKay to co-chair the first session on "Ecological Aquaculture" at the World Aquaculture Society meeting in Washington, DC. Among the pioneers we met at that session was Gerald Schroeder, whose work in Israel affected us and a whole generation of aquaculture ecologists internationally. Lucky for me and hundreds of others, John Bardach moved to Hawai'i and became a leader of the sustainable aquaculture movement (Bardach 1997). I became his doctoral student which launched me into a lovely life of worldwide discoveries of ecological aquaculture.

The Foundations of Ecological Aquaculture

Ecological aquaculture plans, designs, develops, monitors and evaluates ocean/aquatic farming ecosystems that preserve and enhance the form and functions of the natural and social environments in which they are situated. Two overarching, ethical concepts are embedded into the foundation of ecological aquaculture as a field of knowledge: 1) The Hippocratic Oath — do no harm to social and ecological systems and 2) The Precautionary Principle — do not proceed with disruptive innovations when comprehensive scientific knowledge is lacking.

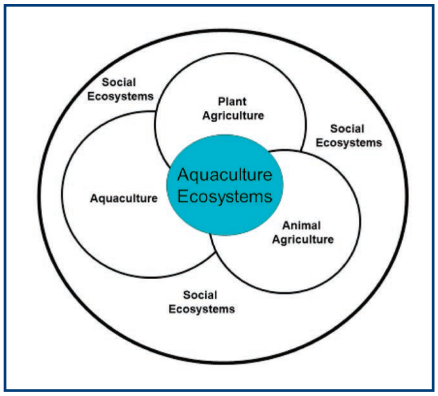

FIGURE 2. *Aquaculture ecosystems mimic the form and functions of natural ecosystems. They are sophisticated, knowledge-based, designed farming ecosystems that are planned as combinations of land and water-based aquatic plant, agronomic, algal and animal subunits that are embedded in the larger context of social systems.*

The overall goal of ecological aquaculture is the adoption of an accelerated social license to develop aquaculture throughout the World. Ecological aquaculture develops "aquaculture ecosystems" designed to deliver both economic and social profit. Such aquaculture ecosystems mimic the form and functions of natural ecosystems. They are sophisticated, knowledge-based farming ecosystems designed and planned as combinations of land and water-based ocean/aquatic plant, agronomic, algal and animal subunits, which are embedded into the larger context of social systems to form unique, social-ecological systems (Fig. 2).

Ecological aquaculture incorporates at the outset — and not as an afterthought — planning for not only the sustainable production of ocean/aquatic foods, but also for innovation, community development and the wider social, economic and environmental contexts of aquaculture at diverse scales, both large and small, and at the commercial, school and homeowner scales. Ecological aquaculture uses the "aquaculture toolbox" to play vital roles in non-food, natural ecosystem rehabilitation, reclamation and enhancement; better known today as the growing field of "restoration aquaculture" (Jones 2017, O'Shea *et al*. 2019).

Ecological aquaculture combines into one common framework the most important social-ecological trajectories for the future of global aquaculture, aligned with the Agenda 2030 and the United Nations Sustainable Development Goals (SDGs): 1) aquaculture for the world's rich vs. aquaculture for the world's poor and 2) aquaculture for rural areas vs. aquaculture for crowded cities and coasts.

Ecological aquaculture uses the rich knowledge of humanity's connections to traditional knowledge systems of aquaculture that date from antiquity to modern aquaculture in all its diverse forms to create a singular, understandable, knowledge-rich developmental pathway for aquaculture into the future.

The Principles of Ecological Aquaculture

There are six key principles of ecological aquaculture:

1) Ecological aquaculture systems are "aquaculture ecosystems" that mimic the form and functions of natural ecosystems, resulting in accelerated environmental profits.

Ecological aquaculture farms are designed farming ecosystems. Sophisticated site planning occurs so that farms "fit with nature" and do not displace or disrupt the forms and functions of invaluable natural ocean/aquatic/terrestrial natural ecosystems or conservation areas. If localized displacement or degradation does occur, active policy and financial support of innovative, collaborative research and development programs for ecosystems redesign, relocation, rehabilitation and enhancement efforts are initiated, supported and communicated to a concerned public by the ecological aquaculture farms throughout the life cycle of their farming operations.

Ecological aquaculture practices nutrient management by using ecosystem design, reuse and recycling and does not discharge any nutrient or chemical pollution causing irreversible damage to natural ocean/aquatic/terrestrial ecosystems. No harmful chemicals or pharmaceuticals potentially harmful to long-term human or ecosystem health are used in ecological aquaculture production processes. Ecological aquaculture farms have "sustainability strategic and implementation plans" in place to develop, manage and communicate comprehensive reuse and recycling systems for all farming operations.

Planetary health (www.thelancet.com/journals/lanplh/home) is a critical part of developing a complete knowledge basis for the design of ecological aquaculture systems. Planetary health provides a framework for the transdisciplinary scientific knowledge needed to produce high-quality foods with no residues of antibiotics, organic pollutants or other well-known industrial toxicants damaging to environmental and human health and wellness.

2) Ecological aquaculture results in accelerated economic profits by practicing trophic efficiency to ensure that aquaculture is humanity's most efficient protein producer.

Design and implementation of aquaculture systems for both lower and higher trophic level species which demonstrate added production of high-quality foods providing multiple benefits to social, environmental and economic health and wellness are the only choices for ecological aquaculture. A global expansion of lower trophic level systems and species in designed ecologies is a priority for ocean/aquatic aquaculture development. Non-fed fish and shellfish comprised 25 million t globally in 2018 (17 million t aquatic invertebrates and 8 million t filter-feeding carps), comprising about 30 percent of all global aquaculture production. Shellfish production was reported at 17.5 million t or 56 percent of all marine and coastal production (FAO 2020). For fed aquaculture, fish meals/oils are not used as either the major protein or energy sources but are included in animal diets to solve issues of diet palatability and human health only. If used as major dietary ingredientt for fed aquaculture species, fishmeals and fish oils originate from certified, sustainable fisheries only or from innovative fisheries management systems planned and regulated to fully utilize and not waste bycatch resources from fisheries (e.g., Iceland). Fed aquaculture ecosystems do not use unsustainable protein and oil sources from agriculture that threatens invaluable terrestrial ecosystems and allied biodiversity (Costa-Pierce 2016). Ecological aquaculture prioritizes science training and industry development for innovations that could result in "game changing" solutions to past quandaries about "farming up marine food webs." Ecological aquaculture expands aquaculture's food production to add to global/local fishery production, practicing efficient ocean resource use and management. Full development of fungal, yeast, bacterial ("bioflocs," Unibio, Calysta, etc.), detrital, insects, and algae (e.g., Veramaris) and other underutilized resources are a high priority for science-based feed developments; contributing to global priorities to develop "circular economies" to feed aquaculture organisms. Fed aquaculture species become highly efficient "ocean/aquatic omnivores" retaining their full nutritional values for human health and wellness (Cottrell *et al*. 2021).

Icelandic law explicitly prohibits discards of fisheries bycatch and provides incentives for compliance. Fishing vessel crews are paid a fixed handling fee for bringing bycatch ashore, encouraging vessels to land all bycatch. Valuable juvenile fish species can comprise only up to a maximum of 10 percent of the catch on each fishing trip. Bycatch can be landed without decreasing the vessel's catch quota on the condition that it is sold at an auction. Proceeds from bycatch sales have created a special fund used to fund marine research. Landed bycatch has fueled a national fishmeal and fish oil industry. (Government of Iceland, n.d.).

3) Ecological aquaculture results in accelerated social profits by integrating aquaculture developments into long-term global fisheries, food and poverty alleviation industries and programs.

Ecological aquaculture is part of the global movement to eliminate extreme hunger and starvation (Millennium Development Goal #1; Sustainable Development Goal #2) by being a part of — not separate from — comprehensive plans for sustainable fisheries for poverty alleviation. Ecological aquaculture systems are scientifically assessed to deliver net gains to food production. In fed aquaculture, evidence of system efficiencies demonstrating provision of new foods to humanity is required, eliminating concerns of "farming up marine food webs" (Stergiou *et al*. 2009).

4) Ecological aquaculture results in accelerated local/regional social/economic profits by integration with communities to maximize local and regional economic and social multiplier effects in order to provide maximal job creation and training within the region.

Ecological aquaculture creates "aquaculture communities" that are an essential part of vibrant, restorative rural developments and working waterfronts. Ecological aquaculture plans for contribution to youth and community social advancement, job creation and environmental enhancement on local and regional scales.

Ecological aquaculture operations export to earn profits but also promote and market products locally to contribute not only to bottom lines economically but also to society. Ecological aquaculture operations are committed to building the "culture" of aquaculture so that "aquaculture communities" can develop and evolve as sources of innovation, education and local pride. Aquaculture development as a means of community development can result in numerous, innovative economic and social multiplier effects such marketing of "sustainable seafoods" that can be certified, but not necessarily. They can be branded locally with pride as local and bioregional, contributing to restaurants that will celebrate their aquaculture products to customers and developing "aquaculture tourism" (Skallerud and Armbrecht 2020).

It is well documented that most aquaculture jobs are not directly in production, rather in affiliated service industries. Dicks *et al.* (1996) found that aquaculture production in the USA at that time accounted for ~16,500 jobs and ~8 percent of total income but that aquaculture goods and services accounted for ~92 percent of the income and ~165,500 jobs, with most jobs in equipment, supplies, feeds, fertilizers, transport, storage and especially processing. Aquaculture development and workforce assessments need to make sure they go beyond production planning concerns and develop comprehensive plans for localization of seed, feed, markets and,

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as much as possible, other aquaculture service industries that produce the most benefits to local economies. Investing in local institutions and employing local professionals as well as importing highly paid professionals from the outside are vitally important, especially for rural development. In Scotland, salmon aquaculture contributes to the long-term viability of many rural, coastal and island areas with year-round, well-paid jobs, plus it supports wider economic growth with its dispersed supply chain including processing, distribution, feed supplies and exports (Weaver *et al.* 2020).

FIGURE 3. *The social-ecological ecosystem of Atlantic salmon farming (International Salmon Farmers Association 2018).*

Feeds, seeds and services imports can be balanced with local provisioners (Fig. 3). Local sales, while not a major income earner for large operations, will over time create an accelerated social license for expansions at scale.

Ecological aquaculture development models create new opportunities for a wider group of professionals to get involved in aquaculture because new advances will be needed not only in technology but also in information, community development and facilitation. Ecological aquaculture for future food security and environmental improvement requires these kinds of more comprehensive planning efforts to evolve an accelerated social contract, especially in its "new geographies."

5) Ecological aquaculture uses native species/ strains and does not contribute to "biological" pollution.

Escapees from aquaculture and aquarium operations have severely impacted aquatic ecosystems worldwide. Exotics species/ strains can be good choices only if: 1) long-term monitoring data and scientific research indicate that exotic species are unlikely to become established, 2) exotic species are widely established, unable to be eradicated and provide demonstrable economic and social profits without irreversible environmental harm, or 3) the use of native species puts at risk indigenous genetic diversity. Ecological aquaculture operations ensure that 1) innovative engineering and escapement technologies are used, 2) control and recovery procedures for escapees are in place, 3) active research and development programs provide alternatives and new options for the development of native species and 4) complete, transparent and public documentation and information are available.

6) Ecological aquaculture is a global partner, producing information for the world, avoiding the proprietary.

Ecological aquaculture farms are aquaculture ecosystems that go beyond "meeting the regulations." They are sites of collaboration, leadership development and innovation. They are outstanding community citizens and models of stewardship. They invest in successful leadership development to trigger innovations in resource efficient appropriate technologies, and more ecologically aligned legislation and regulations.

The FAO Ecosystem Approach to Aquaculture

In 2006, the Fisheries and Aquaculture Department of the Food and Agriculture Organization (FAO) recognized the need to develop an ecosystem-based management approach to aquaculture similar to the Code of Conduct for Responsible Fisheries ("The Code"). It was expected that an ecosystem approach to aquaculture (EAA) would have three main objectives: human well-being, ecological well-being and the ability to achieve both via effective governance within a hierarchical framework that was scalable at farm, regional and global levels. An international group (Fig. 4) was convened in May 2007 in Palma de Mallorca, Spain by FAO's Doris Soto, where review papers were presented (Soto *et al*. 2008), then guidelines developed (FAO 2010).

The EAA is "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. An ecosystem approach to aquaculture, similar to other systems approaches to management, accounts for a complete range of stakeholders, spheres of influences and other interlinked processes." Three principles and key issues at different scales of society were identified:

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.*

Key issue: To estimate resilience capacity or the limits to "acceptable environmental change." A range of terms has been used to estimate the limits to environmental change, 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/ political context. Conventional environmental impact assessments touch on some of these issues. Application of the precautionary approach is important but inadequate in aquaculture; use of aquaculture risk assessments are becoming more widespread (GESAMP 2008).

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

Key issue: Aquaculture should provide equal opportunities for development, which requires its benefits to be more widely shared, especially locally, so that it does not bring detriment to any sector of society, especially the poor. Aquaculture should promote both food security and safety as key components of human well-being.

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

Key issue: Interactions between aquaculture and its influences on the surrounding natural and social environment must be recognized. Aquaculture often has a smaller impact than other human activities, e.g., agriculture and industry, but it does not take place in isolation. There are many opportunities to couple aquaculture activities with other primary producing sectors to promote materials and energy recycling and the better use of resources in general.

Applying an Ecological Aquaculture Approach at Different Scales of Society

Planning for and assessing progress toward an ecosystem approach to aquaculture was determined to be important to society at three scales: farm, watershed/aquaculture and global.

FIGURE 4. *Participants of the FAO Workshop "Building an Ecosystem Approach to Aquaculture," Palma de Mallorca, Spain, May 7-11, 2007. From L to R, first row: John Hambrey, Doris Soto, Salud Deudero, Ricardo Norambuena, Jorge Bermudez, Nathanael Hishamunda, Shirra Freeman. From L to R, second row: José Aguilar-Manjarrez, Bill Silvert, Peter Edwards, Dror Angel, Thierry Chopin, Kenny Black, Alexander Weinberg, Barry Costa-Pierce, Conner Bailey, Francois Simard, Duncan Knowler, Max Troell, Syndhia Mathe, Paul Tett.*

Farm Scale

Planning for aquaculture farms is easily defined physically and could extend only a few meters beyond the boundaries of farming structures; however, the increasing size and intensity of some farms could affect an entire water body or watershed.

Assessment of an EAA at the farm scale entails an evaluation of planning and implementation of "triple bottom line" programs — ecological, economic, and social programs — in a comprehensive manner, using best management practices and the use of restoration, remediation and mitigation methods. Proper site selection, levels of production intensity, use of species (exotic vs. native), use of appropriate farming systems technologies and knowledge of economic and social impacts at the farm level should be considered.

For fed aquaculture, there are wide differences in scale and growth. Aquaculture development models are being modified rapidly by bioengineering, feed, processing and other advances that challenge the concepts of ecological aquaculture. On the other hand, with current trends projected to 2050, large-scale aquaculture could move fully toward ecological aquaculture approaches (Costa-Pierce 2008) as they move to embrace the pathways of "industrial ecology" (Kapur and Graedel 2004).

Watershed/Aquaculture Scale

Planning for an EAA at a watershed/aquaculture scale is relevant to common ecosystem and social issues such as diseases, trade in seed and feeds, climatic and landscape conditions and urban/rural development. Assessment of an EAA at this scale is a two-phase process and includes:

Phase I assessments of inclusion of aquaculture as a part of regional governance frameworks, e.g., the overall framework of integrated coastal zone management or integrated watershed, land-water resource management planning and implementation. Assessments take into account existing scenarios, user competition, conflicts for land and water uses and comparisons of alternatives for human development; impacts of aquaculture on regional issues such as escapees, disease transmission and sources of contamination to/from aquaculture; social considerations such as comprehensive planning for all of the possible beneficial multiplier effects of aquaculture on jobs and the regional economy and considerations of aquaculture's impacts on indigenous communities.

Phase II charts progress toward a full implementation of an EAA at watershed/aquaculture scale and is assessed by measuring the abilities of governments to implement new methods of coastal and water governance to include ecological aquaculture in the:

1) Development of ecological aquaculture approaches that allow the agencies responsible for permitting aquaculture to consider and manage activities impacting aquaculture and ocean/aquatic ecosystems more holistically (e.g., capture fisheries, coastal zone development, watershed management organizations, agriculture, forestry, and industrial developments), such as new mechanisms to communicate, cooperate and collaborate across sectors;

2) Design of ecological aquaculture management zones and parks that encourage aquaculture education, research and development innovations and partnerships, and also emphasize streamlined permitting of integrated aquaculture, polyculture or innovative, ecologically designed, integrated aquaculture-fisheries businesses and initiatives.

Global Scale

Planning for an EAA at a global scale considers aspects of transnational and multinational issues for global commodities (e.g., tilapia, salmon, shrimp, etc.). Assessment of progress toward an EAA at the global scale entails evaluation of issues such as availabilities of fisheries and agriculture feedstocks for formulating aquaculture feeds and these impacts on distant marine and social ecosystems, economic and social impacts of aquaculture on fisheries and agriculture resources, impacts of aquaculture on markets and impacts of globalization on social sustainability (social capital, goods and social opportunities). Applications of tools such as lifecycle assessments of aquaculture commodities and other tools that use innovative social enterprise management guidelines are useful to determine impacts at the global scale (Costa-Pierce and Page 2012).

Progress Towards Adoption of the EAA Guidelines

Brugere *et al*. (2018) reviewed progress towards adoption of the EAA guidelines in the ten years since their release by the FAO. Their assessment found that the uptake of the EAA was "relatively low." The EAA was not playing its anticipated roles in guiding the work,

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strategies and interventions of international and regional development players in the fisheries and aquaculture organizations they studied.

The main constraints facing the implementation of an Ecosystem Approach to Aquaculture was "legislative and regulatory issues, ineffective interagency integration and coordination, financial constraints, lack of human resources, and an ambiguity in the perceived benefits of these approaches by administrators and producers alike" (Brugere *et al*. 2018).

As one of the team members who developed the EAA, the Brugere *et al*. (2018) analysis is accurate for all of the international and local jurisdictions where I either work or live. I see no adoption of the EAA guidelines at any farm, industry, agency, government or non-governmental organization at any of the scales we had hoped to affect in the Americas, EU-27 and Scandinavia, where I have been most active over the last decade.

Full development, promotion and use of the EAA as an overall foundation concept for the future of aquaculture has been virtually absent from the FAO leadership, member states, other partners in governments and industries throughout the world. This is in stark contrast to the years of well-funded work done throughout the world to advance the FAO Code of Conduct for Responsible Fisheries that was adopted unanimously by 170 member countries in 1995. The Code was promoted as a "foundational document that set out globally agreed principles and standards for the use of fisheries and aquaculture resources, including through regional mechanisms and cooperation, to ensure sustainable use of aquatic living resources in harmony with the environment" (FAO 1995).

Recently, the FAO celebrated the 25th anniversary of The Code. There was good cause for this celebration as its key concepts have affected much change. FAO (2020) stated that over 90 percent of fisheries management plans implemented by member countries for marine and inland capture fisheries are in accordance with The Code. In contrast, FAO (2020) mentions the EAA only in passing. The EAA is not mentioned in the FAO (2020) decadal assessment of the important "development of international legal, environmental and management instruments."

During the 10+ years since the EAA there has been a rise of numerous and well-funded aquaculture certification organizations making similar (and sometimes very costly) EAA/sustainability assessments for multiple audiences. As an aside, 15 years ago in ***World Aquaculture*** magazine, we called for aquaculture professionals and industries to pay attention to this rise (Stickney *et al*. 2004). Roheim (2009) estimated that the number of sustainable seafood guides/cards internationally grew to approximately 200. The cacophony of standards and guides has confused consumers, agencies and industries everywhere. Certifications have replaced government scientific agencies, burdened farmers with the need to comply with various competing standards and stymied the development of government legislation and legal frameworks to govern the future of aquaculture. FAO (2019b) has technical guidelines for sustainable aquaculture in development but these are not aligning fully with the EAA as the overall vision, as was done for The Code.

The overuse and degraded state of nearly all of the world's aquatic ecosystems, combined with public concerns about adding any "new" uses or sources of aquatic pollution to already overburdened natural and human systems requires aquaculture and societies to radically transform. The ecosystem approach to aquaculture could be the key organizing paradigm to accelerate the social contract for aquaculture worldwide, as it can ensure aquaculture is a net gain to humanity. For planetary survival in the Anthropocene (Costa-Pierce 2016), a major reordering of global to local food policies and accelerated institution-building and funding are needed urgently to prioritize the rapid, widespread expansion of ecological aquaculture, and for developing fully the FAO ecosystem approach to aquaculture.

Notes

Barry Antonio (aka "BCP", "Pierce") received a Ph.D. in Oceanography and Aquaculture from the University of Hawai'i and an M.Sc. in Zoology and Limnology from the University of Vermont. Currently he is the Henry L. & Grace Doherty Professor of Ocean Food Systems and Program Coordinator of the Graduate Program in Ocean Food Systems, School of Marine & Environmental Programs, University of New England in Maine, USA, and President/CEO of the Ecological Aquaculture Foundation LLC. He is a recent recipient a Knut & Alice Wallenberg Professorship from the Swedish Royal Academy of Agriculture and Forestry at the University of Gothenburg where he serves as a senior advisor to the Director of the Swedish Mariculture Research Center (SWEMARC). Previously, he was the Sea Grant Director for two programs: Rhode Island Sea Grant and Professor at the University of Rhode Island, and the Mississippi-Alabama Sea Grant Consortium at the University of Southern Mississippi. BCP has lived and worked, lived and loved aquaculture and its communities of practice in numerous Asian/Pacific, African, Latin and North Atlantic nations. He has been a WAS member since the 1970s and served two terms on the WAS Board. This article includes excerpts from his upcoming book titled *Radical Aquaculture* to be published by 5m Books.

As a personal note to WAS members, I feel this is a special time we are sharing together. Globally and locally we all are embroiled in the urgency for racial justice, immigration reform and environmental restoration in the midst of a global pandemic. I have learned so much during this time, about the injustices done to many and our Earth, especially from the youth, as I hope you have. This learning has affected deeply my family and the ones I love throughout the World. Personally this has made me to return, proudly, to my real, full, immigrant name of my ancestors, leaving my "deadnames" behind. I dedicate this article to all the beautiful souls struggling to make such radical transformations to themselves, to societies locally and globally, and worldwide for the restoration of Mother Earth.

References

Bardach, J. 1997. Sustainable Aquaculture. Wiley and Sons, New York.

Bardach, J., J. Ryther and W. McLarney. 1972. Aquaculture. The Farming and Husbandry of freshwater and Marine Organisms. Chichester, New York.

Beveridge and Little. 2002. The history of aquaculture in traditional societies. In: Ecological Aquaculture: The Evolution of the Blue Revolution, ed. B.A. Costa-Pierce, pp. 3-29. Oxford: Blackwell Science.

Bookchin, M. 1962. Our Synthetic Environment. Knopf Books, New York.

Bookchin, M. 1982. The Ecology of Freedom. AK Press, Chico, CA.

Brugere, C., J. Aguilar-Manjarrez, M. Beveridge, and D. Soto. 2018. The ecosystem approach to aquaculture 10 years on — a critical review and consideration of its future role in blue growth. Reviews in Aquaculture (2018) 0, 1–22 doi: 10.1111/raq.12242

Costa-Pierce, B.A. 2002. Ecological Aquaculture. Blackwell, Oxford

Costa-Pierce, B.A. 2003. Use of ecosystems science in ecological aquaculture. Bulletin of the Aquaculture Association of Canada 103(2):32-40.

Costa-Pierce, B.A. 2008. An ecosystem approach to marine aquaculture: A global review, p. 81-116. In: Soto, D. et al. (eds). Building An Ecosystem Approach to Aquaculture. FAO Fisheries and Aquaculture Proceedings 14. Rome, Italy. 221p.

Costa-Pierce, B.A. 2013. Ecological aquaculture, p. 174-183. In: Christou, P. et al. Editors. Sustainable Food Production. Springer Reference, N.Y. 1,865 p.

Costa-Pierce, B.A. 2016. Ocean foods ecosystems for planetary survival in the Anthropocene, p. 301-320. In: E.M. Binder (ed.) World Nutrition Forum: Driving the Protein Economy. Erber AG, Austria. 368p.

Costa-Pierce, B.A. and G.G. Page. 2012. Sustainability science in aquaculture, p. 564-581. In: Meyers, R. (ed.), Encyclopedia of Sustainability Science and Technology. Springer Reference, N.Y.

Cottrell, R. and 13 co-authors. 2021. Time to rethink trophic levels in aquaculture policy. Reviews in Aquaculture https://doi.org/10.1111/raq.12535

Dicks, M., R. McHugh and B. Webb. 1996, Economy-wide impacts of U.S. aquaculture. Oklahoma Agricultural Experiment Station, Norman, 946p.

Edwards, P., W. Zhang, B. Belton and D. Little. 2019. Misunderstandings, myths and mantras in aquaculture: Its contribution to world food supplies has been systematically over reported. Marine Policy 106, 03547

FAO. 1995. Code of Conduct for Responsible Fisheries. Rome. 41 pp. http://www.fao.org/3/a-v9878e.pdf

FAO. 2010. Aquaculture development. 4. Ecosystem approach to aquaculture.

FAO. 2019a. GIAHS: Globally Important Agricultural Heritage Systems. In: FAO, Rome. http:/www.fao.org/giahs/giahsaroundtheworld/en/

FAO Technical Guidelines for Responsible Fisheries. No. 5, Suppl. 4. Rome, 53p. FAO. 2019b. Supplementary documentation and analysis towards the preparation of sustainable aquaculture guidelines. Committee on Fisheries. Tenth Session of the Sub-Committee on Aquaculture, Trondheim, Norway, COFI:AQ/X/2019/SBD.2. http://www.fao.org/3/ca5545en/ca5545en.pdf

FAO. 2020. The State of World Fisheries and Aquaculture. Rome, Italy.

GESAMP (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP Joint Group of Experts on Scientific Aspects of Marine Environmental Protection). 2008. Assessment and communication of environmental risks in coastal aquaculture. Rome, FAO. Reports and Studies GESAMP No. 76, 198 pp.

Gon, S. M., III and K.B. Winter. 2019. A Hawaiian renaissance that could save the world. American Scientist 107:232-239. https://doi.org/10.1511/2019.107.4.232

Government of Iceland. n.d. https://www.government.is/topics/business-and-industry/fisheries-in-iceland/fisheries-management/

Groesbeck, A.S., K. Rowell, D. Lepofsky and A.K. Salomon. 2014. Ancient clam gardens increased shellfish production: Adaptive strategies from the past can inform food security today. PLoS ONE 9(3): e91235. doi:10.1371/journal.pone.0091235

Hilborn, R., J. Banobi, S.J. Hall, T. Pucylowski and T.E. Walsworth. 2018. The environmental cost of animal source foods. Frontiers in Ecology and the Environment, 16(6):329-335.

Johnson. T. and 12 co-authors. 2019. A social-ecological system framework for marine

aquaculture research. Sustainability 1, 2522; doi:10.3390/su11092522

Jones, R. 2017. Aquaculture by design: The Nature Conservancy's global aquaculture strategy. TNC, Washington, DC.

Kapur, A. and T. Graedel. 2004. Industrial ecology. In: Encyclopedia of Energy (Cutler J. Cleveland, ed.). Elsevier, Amsterdam.

Lambert, L. 2014. Ancient Aboriginal Aquaculture Rediscovered. The Archaeology of an Australian Cultural Landscape. Academic Publishing.

MacKay, K. 1983. Ecological aquaculture, new approaches to aquaculture in North America. Journal of the World Aquaculture Society 14(1-4): 704-713.

McLarney, W.O. 1976. Aquaculture: toward an ecological approach. In: Radical Agriculture, pages 328-339 (R. Merrill, Ed)., Harper & Row Books, New York, USA

O'Shea, T., R. Jones, A. Markham, E. Norell, J. Scott, S. Theuerkauf and T. Waters. 2019. Towards a Blue Revolution: Catalyzing private investment in sustainable aquaculture production systems. The Nature Conservancy and Encourage Capital, Arlington, Virginia, USA.

Pierce, B. 1980. Water reuse aquaculture systems in two solar greenhouses in Northern Vermont. Journal of the World Mariculture Society 11:118-127.

Roheim, C. 2009. An evaluation of sustainable seafood guides: Implications for environmental groups and the seafood industry. Marine Resource Economics 24(3):301-310. https://doi.org/10.5950/0738-1360-24.3.301

Rose, S. 2019. The New Alchemists – Could the past hold the key to sustainable living. www.theguardian.com/lifeandstyle/ng-interactive/2019/sep/29/the-new-alchemists-could-the-past-hold-the-key-to-sustainable-living

Skallerud, K. and J. Armbrecht. 2020. A segmentation of residents' attitudes towards mariculture development in Sweden. Aquaculture 521:735040.

Soto, D et al. 2008. Applying an ecosystem-based approach to aquaculture: principles, scales and some management measures. In: Soto D. et al. (eds.) Building an ecosystem approach to aquaculture. 14 Rome: FAO fisheries and aquaculture proceedings. FAO, Rome

Stergiou, K, A. Tsikiliras and D. Pauly. 2009. Farming up the Mediterranean food webs. Conservation Biology 23:230-232.

Stickney, R., S. Shumway and B. Costa-Pierce. 2004. The sustainable seafood movement. World Aquaculture 35(1):4-5.

Todd, N. 2006. A Safe and Sustainable World. The Promise of Ecological Design. Island Press.

Weaver, R., J. Hanks, J. Low, J. Flint, C. Nixon and A. Ferguson. 2020. Supporting the Economic, Social and Environmental Sustainability of the UK's Marine Sectors: A research report for Marine Scotland. Scottish Government. https://www.gov.scot/publications/supporting-economic-social-environmental-sustainability-uks-marine-sectors/