Radical Aquaculture: Transformational Social-Ecological Systems that Advance Sustainable Development Goals

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Preface — Why Another Adjective in Front of 'Aquaculture'?

I could have chosen my favorite adjective — "ecological" — to put in front of aquaculture, or "sustainable" or "sustainable ecological" or given up completely into jargon that no one even in the aquaculture fraternity would understand. I could have chosen the most popular of them all "Integrated Multitrophic Aquaculture" and honor my dear friend, Thierry Chopin, and sang loudly the IMTA song, but that would be disconcerting to one of IMTA's most active critics, my other dear friend, Peter Edwards; but I have chosen the adjective "radical." Not that it is going to be acquired as yet another community of practice to join the many (see Fig. 8 in Costa-Pierce and Chopin 2021). Rather, I choose this adjective to make a statement of urgency, as a global clarion call for much more active and direct engagement by our global aquaculture community, especially our new generation of leaders, to advocate more forcefully for the expansion of aquaculture systems at all scales of production. After watching the global leadership dysfunctions exhibited clearly at COP 26, one of my colleagues stated that the youth of the world want us who are in the sunset years of their careers to do everything we can do to help make the 2020s the "decade of doing."

> Progress in incorporating ecological aquaculture and the concepts of an ecosystem approach to aquaculture will require development of education programs that promote broad awareness of the diversity of systems, species and their allied social-ecological, policy, communications and economic issues. Global centers of excellence are needed with their leaders broadly trained, collaborative and adaptive so that they listen with "big ears" and can incorporate new developments and diversity into management approaches and policies that can quickly reorder established norms.

I've taken the title of my upcoming book *Radical Aquaculture* in honor of a group of senior leaders who gathered together — they led "the do" a long time ago — and affected me as a restless youth. They published an impactful terrestrial counterpart to mine many years ago, *Radical Agriculture* (Merrill 1976). Radical means "roots." Getting to the roots of aquaculture as our current food production, consumption, and value chains — at all scales — needs the radical transformations that aquaculture can provide.

In this last of four articles for ***World Aquaculture*** this year, I'll continue my polemics, which are "the art or practice of engaging in controversial debates or disputes" on the world, the future of food and aquaculture, discuss the relevance of transformation concepts, give examples of radical transformations of aquaculture that have and can change some of the alarming trajectories of our time, which, given time, may have the potential to change our ways of life on Earth Ocean.

Continuing Debates on Orthodoxies and Hype

Costa-Pierce and Chopin (2021) questioned the new orthodoxies and hype in aquaculture. Zajicek *et al*. (2021) have added and clarified more of these in their recent review countering with facts on a "…variety of longstanding and inaccurate myths and assumptions directed at offshore aquaculture farming and its regulation…foisted on the public." Among the most interesting new debates have been those stirred by Belton *et al*. (2020) who concluded "…that marine finfish aquaculture in offshore environments will confront economic, biophysical, and technological limitations that hinder its growth and prevent it from contributing significantly to global food and nutrition security." They argued that land-based freshwater aquaculture is a much more favorable production strategy than ocean/marine aquaculture; disagreed with government and non-governmental organization (NGO) spatial planning efforts that add new aquaculture operations to existing ocean uses; advocated for an open commons for small-scale capture fisheries as opposed to aquaculture; and opposed open-ocean aquaculture and other types of industrial, capital-intensive, 'carnivorous' fish aquaculture. An international group has responded (Costa-Pierce *et al*., in press); strong debates will continue.

Belton *et al*. (2020) opinions may have currency if high-level policymakers and financial institutions take them seriously. If so, they will weigh disproportionately the positive merits of freshwater aquaculture on their environments and societies and neglect to involve the hundreds of aquaculture scientists and industries who work in all salinities of water, at all scales of development, worldwide. If so, Belton *et al*. (2020) will have succeeded in breaking global aquaculture into oppositional parties, fracturing the small international aquaculture research and development community into freshwater versus marine, nearshore versus offshore, small-scale versus large-scale, fed versus extractive, and aquaculture developing nations versus aquaculture developed ones. We will again be set back in our approaches to educate decision-makers, regulators, investors, communities and consumers who are already struggling to understand aquaculture, especially in the new geographies for aquaculture of the world outside Asia.

Introduction — Radical Transformation

Radical transformation involves accelerated and more widespread investments in the global adoption of aquaculture innovations of systems, scales, places and behavior changes. Pereira *et al*. (2018) stated that "transformation is required when there is a need to create fundamentally new systems because ecological, economic

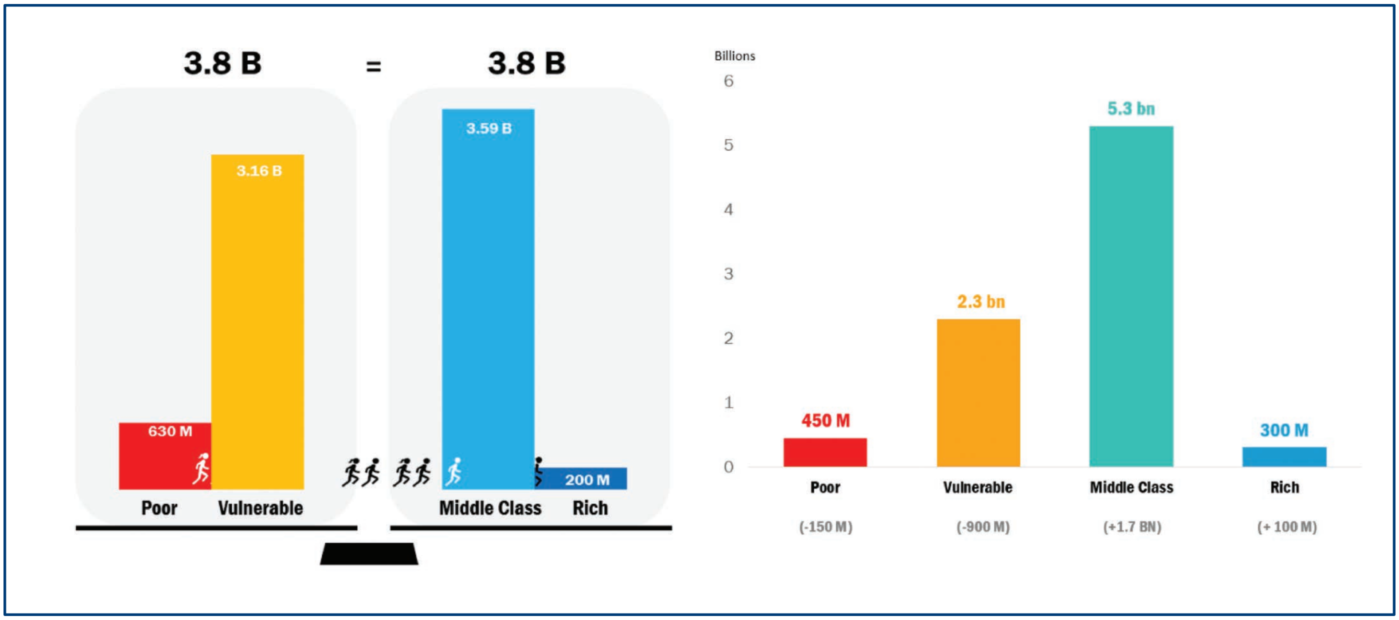

FIGURE 1. *The rise of the middle, consumer class globally (Kharas and Kharas 2018).*

or social structures make the existing systems untenable." Radical transformation involves vigorous debates on the abilities of aquaculture to make fundamental changes to societies.

Application of transformation thinking and processes occur in aquaculture. Culver and Castle (2008) were one of the pioneers. They "intentionally engineered a clash of cultures" as they tasked an interdisciplinary group of aquaculture experts take up various parts of a provocative question: "Does Canada — the world's largest ocean nation — want to become an 'aquaculture nation' and if so, how?" There are numerous radical transformations one could feature. One is the rapid transformation in resource extraction, use and developments in aquaculture feeds that have led to the evolution of fed aquaculture species becoming highly efficient "aquatic omnivores" (reviewed recently by Zajicek *et al*. 2021 and Costa-Pierce *et al*. in press). Here I feature excerpts from *Radical Aquaculture*.

Radical Transformation — Investors Move Away from Industrial Agriculture and Choose Aquaculture

Increased future food demands have been the subject of many analyses by agriculture professionals. Serious concerns have been raised about the environmental consequences of increased land conversion due to the expansion of meat and soy production and their adverse impacts on climate and terrestrial ecosystems. DeFries *et al*. (2015) called the increased consumption of meat, especially red and processed meats, a global human health and wellness crisis.

Agriculture is projected to consume all of the remaining fertile lands of the world (Bruinsma 2009). Unsustainable practices such as soil degradation, deforestation, water resource scarcities, pollution and wastes due to the expansion of agriculture are increasing worldwide. Agriculture planners rely upon a continued expansion of arable lands into what they call "unfavorable agroecological lands and often also unfavorable socioeconomic environments" (Bruinsma 2009); in other words, into the Earth's last remaining terrestrial ecosystems, parks, and bioreserves for Nature and the homes of thousands of indigenous peoples (Morton *et al*. 2008). Bruinsma (2009) states that about 90 percent of the remaining 1.8 billion ha of available arable lands are in sub-Saharan Africa and South America, and "half is concentrated in just seven countries (Brazil, Democratic Republic of the Congo, Angola, Sudan, Argentina, Colombia, Bolivia)." These countries are expanding industrial agriculture for food and non-food exports, e.g., oil palm, biofuels and soybeans.

Agriculture analysts continue to rely upon the concept of "sustainable intensification" of agriculture to prevent additional conversion of the Earth's last remaining invaluable terrestrial ecosystems to farms. Crist *et al*. (2017) state that "it appears questionable whether sustainable intensification can prevail over biodiversity-encroaching food production trends." Tillman *et al*. (2001) conclude that sustainable intensification cannot meet rising food demands and would not work as a global strategy anyway because it would have to be implemented everywhere globally to make a difference.

There have been numerous high-level and very well-funded studies by technologists, geographers and food policy professionals on how to meet the world's current and future food needs. However, until very recently, nearly all of these cogent analyses regarding the future of food consider food to be terrestrial foods. Foley (2015) proposed five important steps to increase food production: 1) freeze agriculture's footprint, 2) grow more on farms, 3) use resources more efficiently, 4) shift diets and 5) reduce waste. These are all reasoned and admirable goals to change the trajectory of agriculture. Reforming agriculture is vital but this five-step solution and the concept of sustainable intensification of agriculture will not be enough to save our planet from ourselves. Pretty (2018) claims sustainable intensification increases overall food system performance without unacceptable environmental costs but fails to mention the greatest opportunity to improve healthy food production at the lowest environmental costs — the rapid expansion of aquaculture.

Aquaculture, by its very nature, has the ability to be integrated into and be restorative of oceans, lakes and water systems throughout the world (TNC 2021) and is therefore most worthy of radical transformative opportunities for the future of food (Naylor *et al*. 2020).

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Expansion of aquaculture can be done without any further pressure on marine or freshwater fisheries or agriculture. Aquaculture can move millions of people away from unhealthy, overly processed/refined foods into fresh vegetables from integrated agriculture-aquaculture farming systems, aquatic permacultures and into highly efficient ocean/aquatic "industrial ecologies." Such food-producing systems can achieve full utilization of everything produced; where wastes become valuable resources (de la Caba *et al*. 2019) for both fed species as aquatic omnivores and unfed species of aquatic animals, crustaceans, seaweeds and marine plants.

Ocean/aquatic food production is estimated to comprise only 6 percent of all human foods today. Aquaculture is an ancient practice in a few parts of the world but large-scale aquaculture with global to local value chains is only about 50 years old, is poorly understood and requires much more additional investment and development. Unfortunately aquaculture remains neglected by both policymakers and the public where it can provide the most benefits of food, environmental restoration and climate mitigation to meet sustainable development goals. As a result, there are very few aquaculturally developed nations on Earth today. Aquaculture production is not increasing as rapidly as it needs to in order to become an important contributor.

Radical Transformation — Consumers Choose Aquaculture Products and Bennett's Law is Broken

Although the COVID-19 pandemic has disrupted economies and supply chains worldwide (Belton *et al*. 2021), the trajectories of global economies were already undergoing a dramatic reordering of global wealth. Regional poverty and human misery remain a concern — due principally to political/social conflicts and wars — but the dramatic North-South wealth disparities of 50 years ago have changed. China's middle (or consumer) class exceeds 400 million persons and by 2050 the middle class of India will rise to 500 million (Crist *et al*. 2017). Kharas and Kharas (2018) identified 2018 as a global tipping point when half the world was in the middle class or wealthier. By 2030, they predict the global middle class will grow by 1.4 billion people to 5.3 billion and comprise the world's largest economic grouping (Fig. 1). Such trabsformative changes have resulted in some communities in rich countries experiencing poverty at the levels of poor nations, and vice-versa.

Bennett's Law (Bennett 1941) states that, as people enter the middle class, diets change from being based largely on starchy staples to diets that incorporate increasing amounts of red meats, dairy and refined foods (Popkin 1998). The worldwide market penetration of farmed salmon is an example of what aquaculture can achieve to relegate Bennett's Law to history. Salmon is available throughout the world not only to urban middle classes but also to rural consumers. After reviewing the alignment of the sector towards UN Sustainable Development Goals, Torrissen *et al*. (2011) concluded that Atlantic salmon farming can be compared to raising a marine "super chicken," producing one of the "most sustainable meat products in the world food market." Certainly this ranks as a radical transformation of global food systems, but this consensus finding could be much more impactful as it continues to be challenged by institution leaders, policymakers, advocacy groups and consumers, even as salmon production systems and associated environmental impacts have decreased in the decade since this review was published. This is due to a lack of education and the inability of aquaculture to reorder established norms, which is why we need a radical transformation of aquaculture.

Radical Transformation — The Institutions and People in Aquaculture Reorder Established Norms

Radical transformation of aquaculture is vital at the institutional and personal/consumer levels as we need behavior change. Problems are systemic. There are institutions and programs to emulate and much progress that gives great hope that radical transformative changes have occurred, are happening, and could change norms..

Aquaculture is a garrulous menagerie of disruptive social, ecological and technological systems undegoing rapid advances. In most regions of the world it remains an obtuse, little known and neglected field. It is perceived by some as a threat of disruption to traditional academics and environmental management regimes and to exisiting fisheries, agriculture and environmental systems and norms. Professional, regulatory, 'decision-maker communities' in aquaculture are dominated by agriculture, fisheries, natural resource managers and conservation professionals who have little knowledge, training or direct experiences in aquaculture with its unique policy needs (Urquhart 2010). Many regulate operations they have no experience in or, at worst, have never visited. Aquaculture and fisheries are so separate structurally and functionally in many countries' governance systems and academic institutions that such institutions and professionals have lost track of their common goal of delivering environmentally friendly, safe and environmentally responsible seafoods to the people they serve.

All food production systems have environmental and social impacts. Sensible regulatory alignments are needed to deliver products that sustain livelihoods. More broadly there is a need for institutions to train the next generation of these professionals in aquaculture so they can be better at making decisions that also account for the need to sustain society, as well as preserve, restore and enhance biodiversity and natural areas. Radical transformations of governance systems will require new paradigms and changes in institutions and resource flows (Westley *et al*. 2013, Westley *et al*. 2017, Stead 2018, Stead 2019).

Folke *et al*. (2010) challenged our institutions and education systems to continually adapt and create new institutions around the emergence of new questions to address changing social compacts and create new institutes of food, energy, water, waste and shelter, not only of biology, chemistry, economics and architecture. The National Research Council (2000) stated that more attention needs to be given to educating the next generation of leaders by teaching metacognitive skills by practicing different ways of thinking in a variety of contexts with less emphasis placed on trying to fill students with a large volume of facts and knowledge. Chatterjee *et al*. (2019) observed that graduate students trained traditionally in math, science, technology and engineering lack career management skills that industry mentoring and networking provide. Career exploration and self-development training to enter innovation-rich areas such as aquaculture are vital, especially as tenure-track positions in academia have dwindled.

Industry investments in community-based aquaculture education centers in Norway have paid off handsomely to create an accelerated social license for salmon farming. They are also major tourist attractions (The Salmon Center [Domas Pisces]) in Nordland, Norway, salmoncenter.info/Bodo/English/). In the US, the NOAA Sea Grant College Program has led the way in developing aquaculture education

TABLE 1. Radical transformation of aquaculture – Selected systems and species.

Systems	*Why So "Radical"?*	*Examples*	*References*
Integrated Agriculture-Aquaculture Farming Systems (IAAFS)	Farmers more than double incomes & farmers adopt aquaculture more widely due to cucumbers; S. Thilsted is honored with The 2021 World Food Prize	Ponds and Cucumbers; Size Polycultures in Bangladesh	Karim and Little 2017, Ahmed *et al*. 2014, Thilsted *et al*. 1997, Roos *et al* 2003
Integrated Multi-trophic Aquaculture (IMTA)	Concept has transformed historical concepts of "polyculture" worldwide with many innovations	Bivalves and kelp, N.B., Canada; Mussels and kelp, Maine, USA; Greenwave Connecticut, USA	Turquoise Revolution (Coastal Health Solutions w/Magellan Aquafarms), Bangs Island, GreenWave Regenerative Ocean Farming Systems
IMTA	Aquaculture is so dynamic China always deserves its special place	Sanggou Bay (>240 MT seafood/ year from >30 spp. in ~100 km^2 ocean space) - seaweed/ bivalve aquaculture now most popular;transferability questioned but "the social benefits…higher than the private benefits" (Yu *et al*. 2017)	Fang *et al*. 2016, Yu *et al*. 2017
Discontinuous aquaponics	Advanced knowledge of waste treatment; balancing nutrients from fish systems with nutrient needs of plants for large-scale inland production in rural areas	Very high resource and food production efficiency (1 kg feed to fish produces over 10 kg of human foods)	Superior Fresh, Wisconsin, USA
RAS	Optimal growth conditions; low FCRs, small footprint (2 MT fish on 3 ha), conservation of fresh water; solids separated from seawater used as fertilizers, reduced diseases, mortalities, no predators, parasites, algal blooms, year round production close to markets	Yellowtail RAS, Netherlands, Denmark. Is this the "ocean tilapia"?	Kingfish Zeeland, Nordic Aquafarms
Fishing livelihoods aquaculture: seaweed farming, clam farming	Aquaculture has radically transformed fishing livelihoods	Fishing families add seaweed farms with technical & business assistance to obtain ocean leases, set up/manage farms with free seed, market contracts; Displaced gill netters become successful clams farmers (~125 mil clams/year worth >$12 mil, >500 jobs)	Atlantic Sea Farms, Maine, USA; Cedar Key, Florida, USA, Leslie Sturmer honored with Distinguished Service Award
Offshore shellfish farming	New Zealand pioneers designs, gear, indigenous partnerships; Family owned and run business successes in offshore aquaculture using NZ technologies (as AMH states…in an "atmosphere of anima mundi (Thomas Moore's concept of living a soulful ecology)	New Zealand; American Mussel Harvesters (AMH), Rhode Island, USA; Offshore Shellfish, Brixham, U.K.	Heasman *et al*. 2020, Landmann *et al*. 2021, American Mussel, Offshore Shellfish
Restoration aquaculture	Fundy Salmon Recovery Project with with government, NGOs, aquaculture industry, academia, First Nations. Number of Atlantic salmon returning in 2021 to Fundy National Park highest in 32 years.	National Parks, N.B., Canada	Clarke *et al*. 2016, Christie *et al*. 2016

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TABLE 2. A guide to assist in determinations of the appropriate scaling for aquaculture (modified from Kohl and Foy 2018).

	INSTITUTIONAL ROLES			
	Private	Public	Public-Private	Donor
1. Who has the resources[1], technical knowledge, and incentives[2] to take on the overall responsibility for driving the scaling up process and coordinating among the various participants?				
2. Currently, are target producers for expansion willing and able to pay[3] for expenses for existing farms but also for the additional inputs and investments, and, are there markets for the additional aquaculture products given the business case?				
3. Who has the resources, technical knowledge and incentives to simplify, modify or adapt the existing aquaculture farms to expansion, or to bundle with other products and services, or to develop partnerships to improve scalability by examining its costs/benefits?				
4. Who has the resources, technical knowledge and incentives to drive the necessary financial expansion; mobilize and make available affordable financing for expansion? Who will provide subsidies or price discounts?				
5. Who has the resources, technical knowledge and incentives to import products if necessary to ensure market supply and ensure supply of any complementary services (e.g. logistical, financial, veterinary, etc.) in order to avoid business collapse due to expansion? Who can help be responsive to changes in market demands?				
7. Who has the resources, technical knowledge and incentives for assistance with geographic coverage to process, distribute, market/sell[4] the increased aquaculture products and any necessary complementary inputs or services? How does the existing distribution network compare with a goal to achieve 100% of the expanded target locations and populations?				
8. Who has the resources, technical knowledge and incentives to create the demand for aquaculture products? At what stage of scaling could these roles shift?				
9. Who has the resources, technical knowledge, incentives and geographic coverage to provide the additional education, training, technical assistance and extension services?				
10. Who has the resources, technical knowledge, incentives and linkages to educate consumers resulting from increased expansion of aquaculture?				

[1] *Resources include human, financial and infrastructure.*

[2] *Incentives refer to the business case (risk and return), the policy priorities, and the bureaucratic motivation for a public-sector agency, and the vision, mission and policy priorities.*

[3] *"Able to pay" means the price point would be affordable given the resources or financing available.*

[4] *Distributing, marketing, and selling are combined but each could be provided by different actors.*

programs at all age levels. The State of Connecticut has invested heavily in aquaculture education; for example, the oldest and most known, the Bridgeport Aquaculture High School (www.bridgeportedu.net/domain/2958). Many more of these community based aquaculture education centers are needed, and not just in academic institutions, but in NGOs and aquariums worldwide (a leading example is the work of the Aquarium of the Pacific, Long Beach, CA, USA); industry would do well in creating, cooperating and funding them.

A radical transformation of institutions and people would embrace aquaculture as a transdisciplinary area of global to local scholarship and practice — a "pracademic" (www.youtube.com/watch?v=wSGF6VDh2ys) — that combines the social-ecological wisdom of aquafarming and fishing peoples, their experiences and practical knowledge, with applied science advancements to provide additional economic, environmental and social profits to communities. Aquaculture is a "team science" (National Research Council 2015) that develops social-ecological partnerships of scientists working with fishermen, farmers and civil society who are central to the success of aquaculture. Aquaculture incorporates the knowledge and power of ecological design, ecological engineering and ecological approaches to governance — to implement and then evolve more sustainable aquaculture businesses and farms at family, bioregional and industrial scales. Aquaculture can evolve a whole new generation of leaders who can design and implement innovative production systems with stakeholders (Table 1) that have a higher economic and social benefits from agriculture or fisheries alone and can accomplish full utilization of its products — no wastes, all become resources — thus achieving the change in norms needed to increase the social contract for aquaculture due to the multiple benefits they provide to society.

There are many institutions to take pride in and emulate as models. None are perfect but all exhibit enough of the values above for me to feature. All have provided training and development of learning communities and networking to thousands. As mature institutions that have embraced the wisdom of teaching the "scoping" of aquaculture practices from the local to the global — what activities and peoples we are involved in here are also present elsewhere from which we all can learn. Change is always present in applied academia but the ones I recommend to study — both their foundations, past, presents and possibly emulate in the future — are: the Institute of Aquaculture at the University of Stirling, Wageningen University, Ocean University of China, Asian Institute of Technology, Coastal Resources Center at the University of Rhode Island, and the Department of Fisheries and Allied Aquacultures at Auburn University. All of these are mature institutions founded on deep local to global, applied, transdisciplinary aquaculture and fisheries that created entire new food systems, institutions and trained thousands.

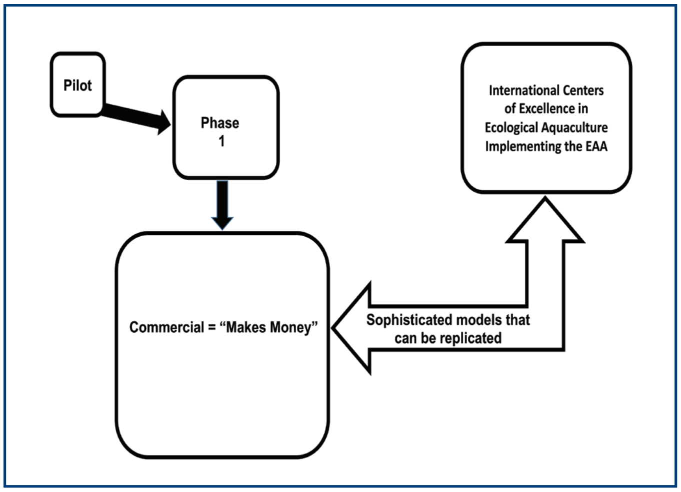

FIGURE 2. *Traditional scaling for new aquaculture development follows a strict industry model of pilot projects that usually are at a very small scale, followed by Phase 1 testing under experimental permits and leasing systems; lastly by commercialization where entrepreneurs promise investors that innovations will make money at a larger scale. Expert discussions which led to the "Bremerhaven Declaration " (Rosenthal* et al. *2012) called for a radically different vision. Interest groups (species development groups) would be formed that would use the principles and practices of ecological aquaculture to select and develop agreed-upon sites as cooperative, science-based testing platforms having international to national partnerships between industry, academia, civil society, agencies, and government at all levels as needed. Platforms would be developed not at small, pilot scales but at meaningful commercial scales. Groups would incorporate the best available participatory knowledge tools for improving knowledge exchange through wider engagement. One result would be the development of better aquaculture governance founded upon the strength of evidence-led aquaculture science developed at the platforms.*

Studies have shown that citizens have a very low awareness of seafood and its sustainability issues, especially in the large markets of Europe and North America. Pieniak *et al*. (2013) asked over 3,000 Europeans six true/false questions about wild versus farmed fish. Overall knowledge was very low with only two questions answered correctly by 50 percent or more. MacKay and Thompson (2019) found a similiar lack of education by American consumers. It remains questionable if consumers can understand the concepts of sustainable seafood and the too many eco-labels to make better choices (Gutierrez and Thornton 2014). However, there is clear evidence that the actions of well-funded NGOs in seafood education can change the views of millions of consumers. The Monterey Bay Aquarium Seafood Watch card has been distributed to over 40 million times and their smartphone app has been downloaded over a million times (Monterey Bay Aquarium, www.Seafoodwatch.org). Tlusty and Thorsen (2016) make a more transformative suggestion for seafood producers and retailers to move away from calling products sustainable; instead, to work towards continually improving their sustainability in practice and communicate those attributes of seafood products. They state that "focusing on measuring the impact of our actions generates a wealth of substance and establishes a direction of travel towards seafood of greater sustainability and…will help educate, inform and inspire consumers to make good choices for their own…."

Radical Transformation — Rationalizing Scaling in Aquaculture

Scale is one of the most controversial aspects of aquaculture today. Conventional scaling models for businesses move quickly from a pilot scale to phase one then attempt commercial viability. All along the way in the new geographies for aquaculture, especially in common property resource areas, scaling issues play a central role in the political and regulatory obstacles to aquaculture (Knapp and Rubino 2016, Stead 2018).

Woltering *et al*. (2019) point to the multiple, systemic problems and failures that new pilot projects, systems and species introductions in agriculture have faced because of the lack of cogent analyses of the scale that was needed to create sustainable systems changes. Kohl and Foy (2018) created a scalability assessment tool for agriculture technologies that every aquaculture revolutionary needs to examine closely and adapt for aquaculture development, especially in aquaculture's new geographies where "big plans" for new aquaculture systems are being considered/developed. A scaling assessment tool for aquaculture using their model is shown in Table 2.

Pro-active, comprehensive analyses of the multiple issues around scaling requires different skills, approaches, and ways of collaborating than those required for the successful implementation of pilot projects. Development actors need a mindset that allows them to navigate creatively across multiple, overlapping systems. A clear vision must be developed about which elements in the system identified actors can and cannot address, and where they need to collaborate strategically to exert influence. Woltering *et al*. (2019) state that, "Although it is tempting to hope for the silver bullet solution that changes the world, we argue for an approach that takes scaling serious in its own right and recognizes the complexities involved in facilitating a transition to a new normal."

As one example of political and regulatory obstacles in a common property resource area, I feature our story here in the Gulf of Maine, USA, a water body with tremendous potential for additional development of both fed and non-fed aquaculture, in a bioregion that has an historical affinity for seafoods, thus has a higher rate of seafood consumption but meets its seafood needs from imports. Conflicts between and within state and federal agencies over the legal protection of endangered right whales have stymied aquaculture developments. This story is unique locally but parallels many I hear worldwide.

Radical transformation is required, and there is another pathway

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(Fig. 2). Rather than halt all aquaculture using the precautionary approach, a new vision would be to develop multiple, well-planned and agreed-upon sites as testing platforms where the table is set properly to have the platform as a strong, science-based international to national partnership between industry, academia, civil society, NGOs, citizen science groups and government at all levels, as necessary. These platforms would be developed, not at a pilot scale, but as cooperative industry development platforms at meaningful commercial scales. They would incorporate the best available participatory knowledge tools for improving knowledge exchange through wider engagement. As stated by Stead (2019), these could develop good governance principles in the context of strengthening evidence-led aquaculture policies. The Bremerhaven Declaration on the Future of Global Open Ocean Aquaculture called to the world for these platforms to be established, stating the need to "organize international R&D platforms involving countries active or intending to initiate…offshore development projects" (Rosenthal *et al*. 2012). For a farm to be established where right whales could be an issue, the best available monitoring, acoustic and other needed and innovative bioengineering technologies would be employed; aquaculture experts would interact with whale experts, government regulators would get real-time in-the-field data for decision-making and everyone would be responsible to the process for full knowledge exchange.

In aquaculture development, the interactions of trade, logistics and infrastructure are oftentimes elements in the matrix of scaling that aquaculture developers neglect but must address. Pro-active planning to realize this and the mechanisms that need to be created to collaborate strategically to exert influence are often afterthoughts in the scaling up of aquaculture developments.

Radical Transformation — Aquaculture Leads Research, Development and Practice (R&D&P) in Ocean/ Aquatic Food Systems

Imagine a meeting of town managers in 1903. They are trying to think of innovative ways to create property rights that will internalize the externalities created by the waste left by horse-drawn carriages in town. As they are deliberating, a noisy new gasoline powered Oldsmobile Curved-Dash Runabout interrupts their debate. They pause for a minute, then resume talking. They have heard and seen the future of transportation and the new problems it will bring, but they continue to discuss the soon-to-be past. Now, fast forward to the present day and consider a meeting of fisheries experts. They debate fisheries management and innovative solutions to the great open-access problems. When they break to eat dinner, it is likely to consist of salmon and/or shrimp. Yet they seem oblivious to the fact that the seafood they are consuming is farmed. They eat the future of fisheries but continue to discuss its past. (Anderson 2002)

More comprehensive training in both fisheries and aquaculture would result in the development of a cadre of transdisciplinary decision-makers who could use systems thinking and approaches (Stead 2019) to conduct the integrated planning necessary for the future of ocean/aquatic foods to meet sustainable development goals. Such plans would include comprehensive considerations of the complex interactions between agriculture, aquaculture, fisheries, natural ecosystems and their allied, place-based, social-ecological infrastructures. None of this will happen overnight, as a much larger investment in education is required. Cooley and Kohl (2016) estimate the average time for scaling a successful pilot or concept to national application is 15 years. FAO (2012) stated that "fisheries and aquaculture interact with increasing intensity as fishers shift from fishing to aquaculture and by competing in the same markets with similar products. The need to integrate planning and management of the two sectors seems vital to their future development and sustainability."

Aquaculture sites are not only economic engines of primary production that can meet the needs and regulations of society but can be sites of innovation and pride if they can be well designed as community-based, aquaculture farming ecosystems. Using systems thinking (Stead 2018) with the ecosystem approach to aquaculture (EAA) can inspire planners and environmental decision-makers at national, regional and local societal scales (FAO 2010). Sophisticated site planning of aquaculture can occur so that farms "fit with nature" (McHarg 1969) and not displace or disrupt invaluable natural, aquatic ecosystems or conservation areas. Ecological aquaculture provides the basis for developing participation with the goal of developing a new social contract for aquaculture that is inclusive of all stakeholders and decision-makers in fisheries, agriculture, ecosystems conservation, restoration and tourism. (Yes, I call for the incorporation, not isolation, of peoples "from away.") Aquaculture needs to be better integrated into overall fishery societal plans for securing sustainable seafood supplies, supporting and restoring fisheries ecosystems; as such, aquaculture's full growth potential lies in its development as a leader of more comprehensive "ocean/aquatic food systems" for "blue bioeconomies."

Radical Transformation — Aquaculture as Rural Development and Connecting to Cities

Bailey (1997) stated that aquaculture developments must include the need for economically viable communities, especially in rural areas where most aquaculture production occurs. The gap between rural and urban areas has grown to dangerous levels, with rural poverty increasing markedly and health and education indicators falling dramatically. The spatial inequality between rural and urban peoples has led to alarming political upheavals. These are global phenomena, with rural communities in rich countries experiencing similar conditions to rural people in developing countries, albeit there are much higher rates of rural poverty in developing countries than in developed countries.

Aquaculture can improve livelihoods substantially by bridging the gap between urban consumers and rural producers. Rural planners and citizens need to take note: this requires leaders to examine closely proposals coming to their communities for medium- to larger-scale food systems, both aquatic and terrestrial, which involve not simply the siting of food production systems on their lands, coasts and oceans, but also the proposals for investments in the localization of allied support services and the building of an educated workforce.

The world's current population is estimated at 7.3 billion persons. Contrary to previous projections, demographers now predict that the global population will not stabilize, and that by 2050 Earth may be home to an estimated 9.7 billion people and upwards of 11.2-12.3 billion by 2100 (Gerland *et al*. 2014). By 2050 the distribution of humans across Earth will be skewed, with most of humanity living in Asia, but Africa will be growing the fastest, followed by Latin/South

America, with slower growth in North America (Table 3). Europe is projected to lose population and India is projected to surpass China as the most populous country (World Population Day, 11 July 2011). Humanity will also be separated spatially and quite dramatically. Seventy percent will live in cities. The largest urban growth will occur in India, China and Nigeria. The world by 2030 is projected to have 43 megacities with more than 10 million people. Rural populations worldwide are expected to decline sharply (United Nations 2014).

Humans will continue their inexorable migration to densely populated coastal cities located on the thin strip of land bounded by coastal oceans. About 40 percent of the 7 billion people today live from the coast to 100 km inland (Sale *et al*. 2014). Sixty percent of the world's 39 cities with a population of over 5 million are located within 100 km of the coast, including 12 of the world's 16 cities with populations greater than 10 million (IPCC 2018). An estimated 100 million people moved from inland to the coast of China in 20 years from 1980 to 2000 (IPCC 2007).

TABLE 3. Demographic shifts in the world's population from 1950 and predicted to 2100 (millions) (Bloom 2011).

Years	*World*	*Developed Countries*	*Developing Countries*
1950	2,500	800	1,700
2000	6,100	1,200	4,900
2011	7,000	1,200	5,800
2050	9,300	1,300	8,000
2100	10,100	1,300	8,800

Projected distribution of world population growth to 2050 (millions) (Chin *et al.* 2011).

Regions of the World	*2010*	*2050*
Europe	738	719
North America	348	447
Latin/South America	590	751
Asia	4,164	5,142
Africa	1,022	2,192

Aquaculture offers a wide range of systems and species options, with many examples of how these have made radical transformations (Table 1). Production systems of fisheries and aquaculture at all scales must have economic viability to be sustainable. Off-farm sales (local to global exports) are essential to survival. It is well known that aquaculture farmers worldwide, even those farmers who are food insecure, develop and trade high-value species to earn income for family nutritional, educational and other needs. Seafoods are very valuable commodities. As a result, they are the most widely traded foods in the world (FAO 2020). In less than ten years, India and China have increased seafood consumption by 20 MMT and predictions are that this will increase by an additional 14 MMT by 2025. During this time, China became a net seafood importer and seafood prices in China equalled or exceeded products for export (Broughton and Walker 2010). As seafood demands increase in Asia and Africa, less will be exported and nations in all of the new geographies for aquaculture that have depended on imports will face greater competition for seafoods and increasingly find imports scarcer. Thus, aquaculture production must increase in these regions. As there is a strong preference for marine species in many of these countries (FAO 2020), marine aquaculture development could increase rapidly.

Given these demographic trends, there are two radical transformations that will need to occur globally affecting everyone locally for aquaculture to be more important in the future of food. First, urban consumers globally, especially middle-income consumers in Asia and Africa, need seafoods from rural areas and from imports; thus value chain, logistics planning and development to move aquaculture products in a cost-effective and sustainable manner will be as important as the development of innovative production systems. Second, innovative aquaculture production systems will need to be integrated wherever possible into the food-energy-water nexus with agriculture and fisheries.

Radical Transformation – Logistics, Trade and Decarbonization

Trade impacts aquaculture value chains globally and locally and always must be considered in the planning for new seafood production systems. More than 75 percent of global fisheries and more than 60 percent of fishmeal is traded. Only 7 percent of terrestrial meats are traded. Ninety percent of the world's products are transported on the ocean. Fifty-nine percent of global food miles are accumulated by ocean transport, 31 percent by rail, and only 0.16 percent by air (Poore and Nemecek 2018). Increased volumes of trade and lower costs of transportation can have strong positive or negative effects on the seafood economies of fisheries and aquaculture.

In 2010, China accounted for about 1 percent of US exports of American lobsters by value; in 2019, this exploded to 15 percent and China became the second largest destination for US lobster exports after Canada. Trade barriers come and go with the political winds and can be painful but short lived. Despite the imposition of protectionist tariffs of 37-65 percent to ensure pangasius from Vietnam could not compete with US catfish, pangasius was among the top ten seafoods consumed in the US in 2009 and competed successfully against a wide range of farmed and wild-caught white fish.

Chinese exports of whole frozen tilapia to Africa have posed a challenge to the growing aquaculture production. For example, in 2013, the Chinese province of Hainan produced 441 MT of tilapia and exported around 104 MT. In 2013, Ghana imported close to 3 MT of tilapia from China. Despite making the importation of farmed fish illegal, Nigerian markets have been flooded by imports of farmed Chinese tilapia and catfish due to the skyrocketing demand for fish (businessdaynigeria.com). The Nigerian Agriculture Ministry estimated total demand at 2.6 MMT. For Nigeria, FAO (2020) reported about 750 MT of imports, domestic production of 800 MT, with only about 200 MT from aquaculture.

There is a strong movement towards decarbonization of sea transport and use of renewable energy systems that will affect seafood trade globally and impact global-to-local aquaculture value chains. Shipping produces only 2-3 percent of global CO_2 emissions. The International Maritime Organization (IMO) plans to cut emissions in half by 2050 with the aim of eliminating them. A research and

(CONTINUED ON PAGE 28)

FIGURE 3. *The integration of renewable energy systems and aquaculture is developing rapidly. Pictured is an aerial view of the integrated 200 MW solar energy-fish farm in Zhejiang Province, China. Another 120 MW project is also operational in Jiangxi Province, and more are planned.*

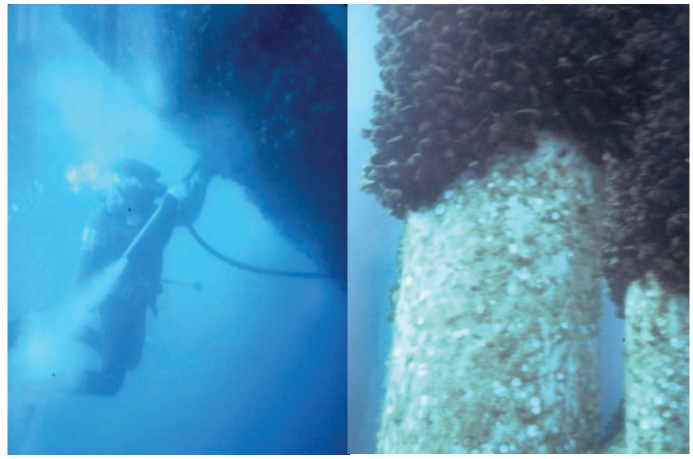

FIGURE 4. *Divers from ECOMAR harvesting mussels using Venturi pumps off the legs of oil platforms in the Santa Barbara Channel, California in the mid-1990s (Photos: John Richards).*

development fund is being proposed by the IMO to provide the capital to develop new technologies. A mandatory levy on carbon fuels of US$2/t would generate US$5 billion over 10 years to explore fuel developments of hydrogen, ammonia, methanol and nuclear. Maersk (Denmark) is planning to launch a methanol-based liner in 2023 and Wallenius Wilhelmsen hopes to launch a wind-powered carrier in 2025 (Ocean Economist 2021).

Radical Transformation – Integrated Aquatic Food-Energy Systems

There have been significant developments to realize more sustainable infrastructure for food systems through the integration of operations for food, energy and water systems (FEWS) (Memarzadeh *et al*. 2019). Saundry and Ruddell (2020), in their book on the food-energy-water nexus, detail the needs for new ecological designs of mixed systems at scale. Agriculture is going through a transformative revolution with the emergence of "agrivoltaics," the integration of land for both solar photovoltaic energy and food production (Harshavardhan and Pearce 2016). Solar panels and crops are placed to optimize crop yields and qualities, energy production and to conserve water. Large-scale, land-based aquaculture systems are similarly going through an exciting innovation phase integrating with renewable energy systems, led by the development of integrated solar fish farms of 120-200 MW in China (Harkell 2020) (Fig. 3).

Buck and Langan (2017) have led research on the integration of offshore renewable energy systems and aquaculture for over 20 years. However Stead (2019) stated that co-location of aquaculture facilities has "come to nothing or had limited success," blaming "the lack of systems thinking and in particular concerns about insurance, access, regulations, risk or governance issues." Although wind-power is well developed in European seas, and worldwide on land, just one small offshore wind energy facility exists to date in the US. Major development plans are moving forward, however. Twigg *et al*. (2020) published a "Special Issue on Understanding the Effects of Offshore Wind Energy Development on Fisheries" in *Oceanography* containing valuable experiences from Europe and the one facility in Rhode Island, USA that are broadly applicable to aquaculture co-location with wind energy. Haggett *et al*. (2020) had especially poignant comments about the need for "meaningful engagement" with fisheries interests.

Much more work needs to be done to articulate fully the benefits to fisheries of offshore structures and the opportunities to use renewable energy platforms for both aquaculture and marine restoration. For example, Claissea *et al*. (2019) provided solid scientific evidence that oil platforms off California are among the most productive marine fish habitats globally. In the 1980s-1990s, oil platforms in the Santa Barbara channel were the sites of three California companies harvesting mussels for sale to consumers and for a biofouling control strategy for oil companies (Richards *et al*. 2009) (Fig. 4). The most successful was ECOMAR, which documented the unique business and environmental strategy and developed all regulatory approvals for human consumption. ECOMAR estimated it harvested US$50,000-75,000 of shellfish per platform every 16-20 months (Meek 1989). Between 1992 and 1997, mussel production rose in California from approximately 84.8 MT to 213.6 MT with most of the new mussel production coming from the southern California oil platform harvests. Development of shellfish harvesting as a biofouling control strategy and profitable business was a win-win situation for both the oil and gas industry and shellfish harvesting entrepreneurs, allowing oil platform operators to reduce or eliminate costs for cleaning stress-load biofouling communities off platform legs and crossbeams, while at the same time providing entrepreneurs an opportunity to develop a valuable new ocean foods market for human consumption.

As aquaculture markets have grown and become more profitable, and as oil and gas prices have fluctuated widely and climate change has become an urgent global priority, oil and gas companies have become major investors in aquaculture both on land and at exposed, high-energy sites remote from the many conflicts rife in the world's coastal zones. The Norwegian offshore oil industry sees profits to be made globally from plans to produce 5 MT of farmed salmon by 2050, the lack of nearshore lease sites to expand production, the technological advancements being made in automation and digital systems and the emergence of industrial-scale recirculating aquaculture systems (RAS) on land.

Norway's Moreld, a major North Sea oil service conglomerate, formed Moreld Aqua to "capitalize on…expertise…from energy management to marine operations" (Holmyard 2021) and China's Three Gorges Corporation sees the growth of aquaculture markets as major growth opportunities. The Three Gorges Corporation is

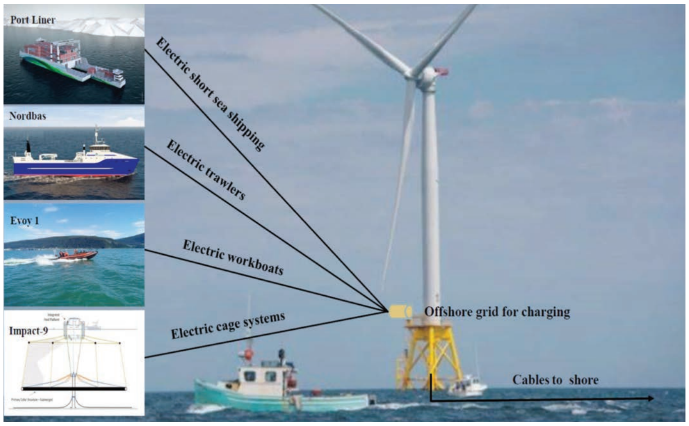

FIGURE 5. *With the commercialization of electrification of offshore shipping and aquaculture, marine food systems integrated into offshore wind energy sites is now a win-win financial proposition for both parties. Offshore grids and charging stations will provide additional income for wind energy companies who now will balance needs for cables to shoreside substations. Electric fishing boats can charge offshore saving travel time and money, and advanced aquaculture systems will use embedded electric energy to manage position in the water column to deflect storm energy, deliver feeds and recover wastes (Background photo: Ørsted).*

constructing 91 turbines, with an investment estimated at $700 million, off Shandong province in the Bohai Sea. They are developing an integrated energy-food business model that will combine aquaculture into the foundations of the turbines by integrating six artificial reefs to grow oysters, sea cucumbers and several species of fish (Yu 2019). Such multi-national energy companies have substantial technological and engineering expertise to design and build new testing platforms for marine aquaculture in exposed sites, to create new decision support and visualization tools for optimizing and de-risk RAS, and to decarbonize aquaculture. Moreld Aqua announced it is developing a hybrid battery and energy management system which will allow remote monitoring and control to lower the carbon footprint of aquaculture. Electrification of operational, management and service vessels has the potential to unlock the offshore fishing and aquaculture economies, and integrated systems may finally be poised for major developments (Fig. 5).

An Aquaculture Tool Kit for Radical Transformations

Marshall *et al*. (2018) discussed the important roles of applied researchers as "transformative space-makers." These leaders are not simply knowledge providers but they help to set the table for transformation to occur, employing experienced facilitators who can bring a variety of tools for participation that are central to both process and content (Wittymayer and Schapke 2014).

Design Thinking

Three pioneers of design thinking whose ideas and works are timeless, and have application for the design of aquaculture ecosystems are: Ian McHarg (1992), John and Nancy Todd (2006) and John Lyle (1999). McHarg (1969) wrote the influential volume *Design with Nature* that transformed the field of landscape architecture to landscape ecology and freed that profession from control by real estate developers (Steiner 2004). Ian McHarg was awarded the National

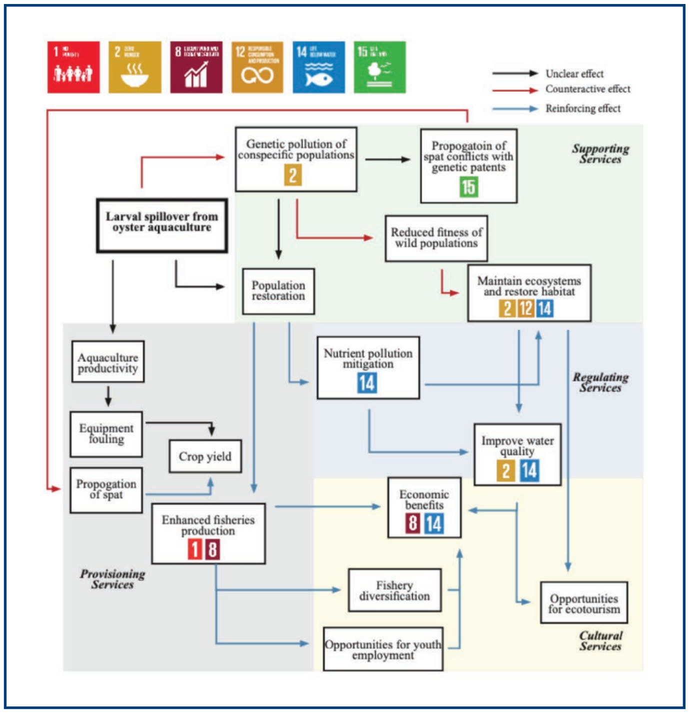

FIGURE 6. *A mental model of the effects of larval spillover from oyster aquaculture that illustrates well The Nature Conservancy definition of "restoration aquaculture" (TNC 2021). This mental model includes system interactions with United Nations Sustainable Development Goals (SDGs) and the four categories of ecosystems goods and services (Delago 2021).*

Medal of Art by US President George Bush who stated at the ceremony that "I hope that in the 21st century the largest accomplishment of art will be to restore the Earth." McHarg's work lives on at Ian L. McHarg Center for Urbanism and Ecology at the University of Pennsylvania Stuart Weitzman School of Design and their "Design with Nature Now" initiatives.

Lyle wrote in *Design for Human Ecosystems* that the design component of scale was one of the three fundamental organizational concepts along with design process and ecological order in shaping ecosystems. He provided 12 regenerative strategies for the foundation of the Center of Regenerative Studies, California Polytechnic State University Pomona, whose focus on regenerative systems was "not so much a focus on technology as it is a deeper concern for shaping an integrative and mutually supportive relationship between humans and nature." Lyle's ideas of regenerative design aligned with concepts of systems thinking and mental models as he emphasized that designs do not have a beginning or an end but are a continuous loop, with opportunities to ask questions and to learn new information, and then to start again with a new, revised set of information.

These pioneers have stimulated a new generation of outstanding ecological designers and architects. Most notable among the leaders is the MASS (Model of Architecture Serving Society) Design Group that implements awe-inspiring architecture that reaches far beyond buildings to "support communities to confront history, shape new narratives, collectively heal and project new possibilities for the future." Lesley Stahl featured the MASS model of community-focused architecture on a recent segment of the US CBS news show 60 Minutes.

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Mental Models

A model is a simplification of a system from which we can learn something. A mental model is an explanation of how its creator thinks the system works. Game theory is a type of mental model that helps understand relationships and trust. Peter Senge, best known as the author of *The Fifth Discipline: The Art and Practice of the Learning Organization* described mental models as one of the five disciplines needed to develop a learning organization. Much of aquaculture is globally dynamic, adapting and transforming in complex social-ecological environments, especially when developing in common property resources in its new geographies. Drawing a mental model is the first essential step towards investigating a system. Too many systems thinkers run too quickly to the software. Farnam Street Media Inc. (2021) has a tool kit that features about 100 types of mental models. Figure 6 is an example of a mental model of the dynamics of transformative oyster restoration aquaculture in Maine, US.

Foresight

Foresight is a set of "future tools" used to create transformative spaces with stakeholders. The Innovation Leadership Board conducts trainings called "Strategic Foresight & Innovation" that uses 'methods cards' to find and implement 'the next big idea' (www.innovation.io).

Stories

Galafassi *et al*. (2018) facilitate and create radical stories of positive futures. Pereira *et al*. (2018) and the "Seeds of Good Anthropocenes Project" and the "Manoa Mash-Up" have been designed to create "radical stories of positive futures in South Africa that focused on increasing the difference of these stories from the present."

Conclusions and Recommendations

The UN Sustainable Development Goals will drive the future of planetary initiatives (UN General Assembly 2015). More integrated, transdisciplinary ways of developing ecologically and socially responsible food, energy, water and waste systems to meet societal needs in the 21st century will be shared globally, with transferable models emulated at both large and small scales. Global initiatives become local and vice-versa as North-South divides evaporate. The ocean will become a central part of the future of food (HLPSOE 2020).

But this needs to be the "Decade of Doing." Where do we start in aquaculture's least developed countries? First, document where your ocean/aquatic foods are actually coming from. Do deep dives into the local/regional seafood production and trade data comprehensively and measure aquaculture development possibilities, their competition and opportunities for cooperation with agriculture, fisheries and imports. Develop market-driven aquaculture assessments, not technology driven aquaculture development hopes and dreams. Stop defining the future of aquaculture on the social-ecological collapse of fisheries. Join in with everyone you know to help recover fisheries and ecosystems at all levels. That means enhancing by all means fisheries and environmental restoration and improvement efforts, and working with the many allied, mixed fisheries-aquaculture systems of capture-based aquaculture and aquaculture-enhanced fisheries. Aquaculture is not asking for huge new areas of ocean next to coastal areas crowded with existing uses. Mostly, it's asking for tiny "donut holes" in common property resources, but even those are controversial; so wash, rinse, and repeat the advice above on long-term participatory processes (Costa-Pierce 2021, Haggett *et al*. 2021).

Freshwater integrated aquaculture has some of the world's greatest potential for aquaculture development and sustainable intensification. Such land-water interactive food systems hold much potential for production increases in the existing pond and irrigation areas of Southeast and South Asia. Small increases in efficiencies could yield much greater production in existing systems. However, it is unhelpful to pit the future of aquaculture as freshwater aquaculture vs. marine and offshore aquaculture, small scale vs. large scale aquaculture and fed vs. non-fed species as per Belton *et al*. (2020). Land-based freshwater producers of all economic classes need more assistance and sharing of technological and social-ecological advancements that marine aquaculture is making, which could be very impactful to their future development. There is much to share, as rich countries have regions where farmers are mired in poverty that mimics those of poor nations.

In Costa-Pierce (2021), I reported that Brugere *et al*. (2018) reviewed progress towards adoption of the FAO guidelines for an Ecosystem Approach to Aquaculture (EAA) and stated that "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"; plus "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." Woltering *et al*. (2019) give a better perspective on these comments in their seminal paper on scaling for sustainable systems change. They cite the International Development Innovation Alliance (IDIA 2017), who define sustainable scaling as the "wide-scale adoption or operation of an innovation at the desired level of scale sustained by an ecosystem of actors." Cooley and Kohl (2016) Management Systems International estimate the average time for scaling a successful pilot or concept to national application is 15 years. That would mean the FAO EAA guidelines would start to be widely adopted and applied by 2025.

I'm happy to report that the FAO EAA appears ahead of this 15-year schedule! At the recent FAO Global Conference on Aquaculture (see all of the valuable global, regional and thematic reviews at aquaculture2020.org), one for the keynote speakers, a senior leader from the Ocean University of China, announced that China would be establishing a Center for Ecological Aquaculture. Msingi East Africa, is an independent organization committed to building industries of the future using a long term market systems to create 500,000 jobs across East Africa by 2030 and has prioritized aquaculture. Msingi is using the FAO EAA as one of its founding principles. The Seychelles National Aquaculture Policy stated as its vision for aquaculture that the nation would be "a small but internationally competitive, knowledge-based industry, contributing to local food security and supplying international niche markets for high-value fish products, which is guided by international best management practices in accordance with the principles of the Ecosystem Approach to Aquaculture and ecological sustainability" (Seychelles 2018).

Progress is slow in the Americas where large-scale aquaculture dominates, especially in nations where export-driven aquaculture is the core of production (Chile) or where aquaculture is a very small part of primary food production (North America, EU). However, Doris Soto, pioneer of the EAA (Soto *et al*. 2008), reports that a new aquaculture policy for Chile under the EAA framework will be in place sometime in 2022. Camelo-Guarín *et al*. (2021) is using data on nutrient fluxes between salmon and mussel farming and to assess IMTA at the landscape level as a way to implement the EAA in aquaculture management areas. In the USA, where bivalve aquaculture is an estimated to represent 39 percent of total production (FAO 2020), Feldman (2021) investigated the value of adding the EAA to oyster aquaculture in Maine. He found direct connections between the EAA and increased oyster value when communicating the EAA in coastal areas around farms and indirect connections to increased oyster value by monitoring water quality to prevent exceeding carrying capacity and involving a broader spectrum of community members as stakeholders in the planning for oyster aquaculture development at all scales. The FAO is also in the process to develop new Guidelines for Sustainable Aquaculture (GSA) (www.fao.org/in-action/gsa/background/en/) that will be launched in 2022 after discussions and acceptance by member countries. It is hoped that the EAA will be featured at the core of the GSA.

As a recommendation to the emerging generation of aquaculture pioneers in the new geographies for aquaculture: get into your NEI (Not Elsewhere Included)! This has been one of the most obtuse (and my favorite) terms in FAO reports; I remember thinking NEI was a Japanese species! But it's one of the greatest, unsegmented, little-reported areas of aquaculture globally that likely is most important locally, and to the future of aquaculture (Metian *et al*. 2019). Is the evolution of the Blue Revolution in this NEI? By the way, freshwater fish NEI is reported as number #10 in global FAO (2020) production, a reported production larger than the entire reported aquaculture production of Africa (2.2 MMT) (FAO 2020). This category includes many wonderful indigenous South American, African, Australia/Asia/Pacific native species that are under development.

Notes

Barry Antonio Costa-Pierce (aka "Pierce", "BCP") received a Ph.D. in Oceanography and Aquaculture from the University of Hawai'i and a M.Sc. in Zoology and Limnology from the University of Vermont. He has a 40+ year career in aquaculture R&D&P with 20 years internationally in Asia, Africa and the Americas, and 20 years as a professor and director of various applied academic programs at US universities and colleges from California to the Great Lakes, and from the Gulf Coast to New England. Currently he is in his "sunset years" as 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 at the University of New England in Maine. He is also President/CEO of the Ecological Aquaculture Foundation (EAF, oceanfoods.com) and will soon be serving full time in that role. EAF is developing operations in Maine and with partner farms and companies in Florida, Hawaii, Portugal and the UK, and serves as an advisor to Sweden's new Blue Food Centre, AquaSpark (Netherlands), and Kaua'i Sea Farms (Hawai'i).

This four-part series in ***World Aquaculture*** are excerpts from BCP's upcoming book, *Radical Aquaculture*, to be published in 2022 by 5m (Essex, UK). I want to give my deep appreciation to Dr. John Hargreaves, the Editor of ***World Aquaculture***, for the opportunity to write these four articles in 2021. John has taken the magazine and our Society to a new level of outstanding quality. Muito obrigado, meu amigo, John.

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