AGRICULTURE AND ENVIRONMENTAL SERVICES DEPARTMENT

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Growing Aquaculture in Sustainable Ecosystems

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KEY MESSAGES

- Aquaculture is among the most sustainable of animal protein production systems.
- Growth of aquaculture is needed to meet employment and food security targets in developing countries.
- Investment risk co-varies with environmental risk to influence sustainability.
- Existing certification standards do not effectively address ecosystem sustainability.
- Priorities of local communities should inform target setting for employment and conservation.
- Locally adapted aquaculture zone management can reduce environmental and investment risk.

Driven by increasing population, wealth, and the health benefits of seafood, demand for finfish and shellfish exceeds estimated total sustainable catch of wild fish by nearly 100 percent (TEEB 2010). Due to high local demand and temperatures, aquaculture is and will probably remain a business dominated by developing countries, where aquaculture employed an estimated 16 million people in the value chain (0.3 pers-years per ton of fish delivered to market) in 2010, half of which were women. Aquaculture is already a credible economic engine and seafood production system, having contributed 40 percent—some 60 million metric tons—to total supply in 2010 (FAO 2012). Nearly doubling in the 13 years from 1995 to 2007, aquaculture needs to nearly double again in the next 15 years to ensure the global seafood supply (OECD 2010). However, to secure the benefits of a robust aquaculture sector over the long term, the industry must respect ecological limits to growth.

Aquaculture involves a diverse array of production schemes, technologies, and species, and thus it is impossible to provide a single estimate for its ecological footprint (Boyd et al. 2007; Lorenzen, Beveridge, and Mangel 2012) except at the coarsest of scales (Hall et al. 2011). Most of the available data, however, indicate that aquaculture compares favorably to other animal farming in terms of feed efficiency, eutrophying nutrients, freshwater consumption, and land use (see Table, below).

Nevertheless, increasing competition for land and water are driving intensification that sometimes push the limits of ecosystems to absorb impacts and thus increase the risk of catastrophic failure. It is in no one's interest that aquaculture grows beyond the carrying capacity of the local environment. To optimize the cost-benefit ratio of investments in aquaculture development, one needs to determine what kind of regulatory framework, institutional

TABLE. COMPARISON OF SUSTAINABILITY INDICATORS AMONG ANIMAL PROTEIN PRODUCTION SYSTEMS

	Food conversion (kg feed/kg edible weight)	*Protein efficiency (%)*	*N emissions (kg/ton protein produced)*	*P Emissions (kg/ton protein produced)*	*Land (tons edible product/ha)*	*Consumptive freshwater use (m^3/ton)*
Beef	31.7	5	1,200	180	0.24–0.37	15,497
Chicken	4.2	25	300	40	1.0–1.20	3,918
Pork	10.7	13	800	120	0.83–1.10	4,856
Finfish (average)	2.3	30	360	48	0.15–3.70	5,000*
Bivalve mollusks	not fed	not fed	-27	-29	0.28–20.00	0

**Note:* Consumptive use is difficult to compare across the wide spectrum of aquaculture production systems. In the vast majority of cases, water outfalls from aquaculture are much cleaner and more easily recycled than for land animals.

Source: Phillips, Beveridge, and Clarke 1991; FAO 2003; Hall et al. 2011; Bouman et al. 2013.

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arrangement, and monitoring of ecosystem sustainability make the most sense for mitigating the impacts of our seafood production system and managing risk.

CERTIFYING SUSTAINABILITY

To guide consumers about sustainability, seafood certification seeks to create market incentives designed to encourage producers to reduce environmental impacts. Aquaculture certification schemes certify individual farms or, in a few cases, collectives of small farms. However, the most significant negative ecological impacts of aquaculture—loss of biodiversity and eutrophication—do not occur at the farm level, but rather reflect the collective impacts of all farms, certified or otherwise. An objective determination of environmental sustainability needs to move beyond the farm level to that of the larger aquatic ecosystem, of which aquaculture forms only a part.

Systems to ensure ecosystem-level sustainability of aquaculture should aim to sustain indigenous species abundance and diversity at desirable levels and will require (a) spatially explicit regulatory/zoning instruments to define the boundaries over which aquaculture sustainability should be assessed, and (b) sustainability indicators and monitoring systems in respect to the local ecological carrying capacities of these zones. Institutional arrangements that assure compliance and transparency will be needed to operationalize the system.

Planning at the ecosystem level will simplify permitting and ensure that farms occupy less environmentally sensitive areas. Within zones, collective action among farms and with veterinary services to control diseases would be made easier. Once established, zoned aquaculture areas could be certified collectively so that all farms have access to markets. Norway and Scotland (salmon) and Ireland (bivalves) have pioneered user-friendly approaches to ecosystem-level management based on extensive, heuristic carrying capacity datasets that could inform initiatives elsewhere. Australia and New Zealand are exploring aquaculture park leasing arrangements for salmon and shellfish.

With increasing wealth, health consciousness, and global population, demand for seafood is increasing. At the same time, scarcities of water, arable land, and power, combined with unstable climates, will make growing food increasingly challenging and costly. Governments may be tempted to compromise long-term sustainability to meet short-term employment and food security targets. Sustainability should be defined in ways that the public understands so that policy makers and resource managers can fulfill their public trust responsibilities for safe seafood supplies, thriving communities, healthy ecosystems, and biodiversity.

INVESTING IN SUSTAINABILITY

Aquaculture, as a relatively benign system for the production of nutritious food, can make an important contribution to global food security, but new investment of $100 billion, at the very least,[1] is needed to meet anticipated demand. The generally small scale and organic growth of aquaculture has made it difficult to regulate and contributes to the high levels of risk perceived by potential new investors. Because disease and negative environmental impacts, the major exogenous risk factors in aquaculture, are determined primarily by water management, production intensity, and proximity of fish farms to one another, there are clear incentives for responsible aqua-farmers to support zoning and ecosystem monitoring to ensure sustainability and protect their investments.

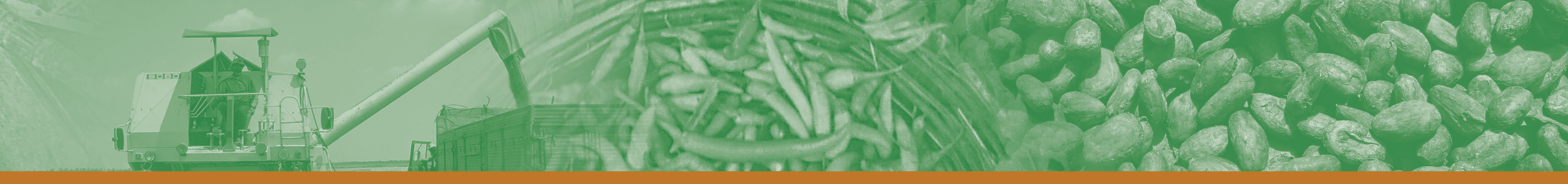
Useful sustainability indicators should reflect an understanding of how ecosystems function and the services that the public expects functional ecosystems to generate. They should also be robust and easy to monitor, and would necessarily be determined by the ecosystem and informed by local priorities rather than by farmed species or culture system. A definition of aquaculture sustainability that rings true with the larger society will capture complexity in a relatively simple index comprising a limited number of iconic indicators.

Life Cycle Assessment (LCA) seeks to define sustainability in the broad sense by comparing food production systems in terms of impact on processes that govern global biogeochemical cycles (Pelletier and Tyedmers 2008). Some LCA indicators (for example, acidification, ecotoxicity, eutrophication) are relevant at the ecosystem level (for example, Ford et al. 2012). Cury et al. (2011) and Smith et al. (2011) have explored trophic cascades that might be adaptable as local indicators of ecosystem stress. For these approaches, however, data and analysis to support a practical local definition of ecosystem sustainability and cost-effective monitoring system are generally lacking.

To be effective in project design and implementation, we need a narrower definition of sustainability that includes the establishment of a workable approach to ecosystem-level management. This should be a joint effort between the public regulatory, research, and veterinary services and private sector investors. Concerted research that could establish a testable framework for ensuring aquaculture sustainability for piloting would:

- Develop a simplified biodiversity/water quality index of sustainability at the ecosystem level;

1 Industry estimate of cost at 2012 prices of building typical aquaculture farms to double supply, not considering new technology.



WHAT'S IN IT FOR ME?

Compliance with aquaculture zoning will depend upon the degree to which stakeholders perceive advantage in collective ecosystem management. Cost/benefit analysis must consider constraints imposed upon resource users as well as returns on investment in the conservation of ecosystem services. Costs will include limitations on farmer behavior within zones, scientific monitoring and the need for communication and collaboration among farmers and between farmers and regulators. Motivations to establish and operate sustainable aquaculture zones vary among stakeholders, but the benefits are many:

What's in it for farmers?

- Reduce risk of poor stock performance, disease and fish kills;
- reduce the cost and complexity of environmental impact assessment;
- lay the framework for a new approach to certification and increase market access;
- improve sustainability—economic, social and environmental—of aqua-businesses;
- demonstrate good stewardship of the environment;
- lower insurance rates and ease credit terms on demonstrably lower risk investments.

What's in it for regulators?

- Credible scientific basis for decision-making on numbers, sizes, intensities of operations in a marine/aquatic space;
- credible scientific basis for aquaculture governance and all interactions with civil society;
- credible scientific basis to increase both local and export market access for "green" products.

What's in it for society?

- Wise use of ecosystem services;
- sustainably produced, nutritious seafood for those who need it most;
- better and fairer management of resources used to produce aquatic food.

What's in it for the environment?

- Assure that an assessment of sustainability captures the collective impacts of all aquaculture operations in a clearly defined area;
- make sure that changes attributable to aquaculture are clearly related to changes in the ecosystem;
- streamline regulation to be more cost-effective.

- Adapt spatial planning to aquatic ecosystem delineation and aquaculture zoning; and
- Elaborate institutional frameworks for adaptive management, monitoring, and enforcement.

Ecosystems in which aquaculture and other human activities occur will change, but not all change is bad. Well-managed aquaculture generates modest (relative to the goods and services it generates), often unnoticeable, changes that do not upset the natural balance of the ecosystem. In many cases, impacts of aquaculture will be positive in terms of ecosystem services. Indicators of sustainability should capture these changes to enable sound management.

CONCLUSIONS

To improve the climate for aquaculture investment so as to sustainably meet food security and economic development targets without causing environmental degradation, a new approach to managing growth is needed. Spatial planning will identify best sites that are good for aquaculture, away from environmentally sensitive areas and amenable to appropriate monitoring. As indicators of sustainability, existing certification systems are not adequate. Needed are objective indicators that take into account the collective impacts of aquaculture at the ecosystem level.

Opportunities exist to learn from existing initiatives in Australia, Ireland, New Zealand, Norway, and the United Kingdom. These should be assessed for robustness and applicability across a range of likely ecosystems where aquaculture is practiced (for example, tropical lagoons, floodplain rivers, coastal bays, estuaries, coral reefs, and so on). The level of impacts from aquaculture that is tolerable should be assessed for a range of ecosystem services considered indicative of ecosystem health and the wishes of informed local communities. Reliability and practicality (including cost-effectiveness) of measurements should be considered in the selection of indicators.

Where there are existing data, pilot projects with the private sector could be launched to field-test this new monitoring and evaluation strategy within two years. Key elements would include the following:

Ecological Issues

- Siting: Identify zones that are good for aquaculture (for example, access to markets and production infrastructure, deep water, fast currents, protected from storms, unpolluted) and that are away or downstream from important ecosystem and biodiversity assets (from, coral reefs, beaches, eel grass beds). This is roughly the subject matter of spatial planning.
- Carrying Capacity: Measure exactly what is happening in the ecosystem and how fast collective production within the zone is approaching some limit. This is mostly basic ecological research.

Institutional Issues

- Setting Limits: Establish with the local community and other key stakeholders the main criteria for impact assessment and acceptable limits of ecosystem change in light of the local culture and economy.
- Enforcement: Establish a regulatory framework based on the above, giving authority to some local agency to enforce rules. This also requires some kind of aquaculture trade association that represents the interests of the aquaculture value chain to government and competing industries, and exercises a useful level of control over its members.

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2 This opinion was elaborated through an extended dialogue among the contributors and does not necessarily reflect the positions of the institutes with which they are affiliated.