

# Socio-economic factors affecting aquaculture site selection and carrying capacity

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## Abstract

The location of aquaculture activities has historically been based on a combination on local demand and agro-ecology, with global demand and deteriorating capture fishery stocks having an increasing influence. External interventions aimed at stimulating aquaculture in developing countries have often been driven by geography and objectives with little regard for other key criteria for successful aquaculture, often resulting in limited development and sustainability. Attempts to restrict certain types of aquaculture or limit them within zones have often failed, especially in countries with weak governance. Aquaculture has potential to exert significant social and economic impacts through upstream and downstream links around the use of chemicals, wastes expelled, and stock migration. This incorporates a broad section of people as stakeholders. Similarly, employment along the value chains, both upstream and downstream, bring benefits to many not directly involved in farming. They considered that focus in development programs should be placed on identifying and responding to local factors, rather than allowing top-down, external factors to dominate. Community stakeholder engagement needs to be strengthened, with more rigorous application of cost benefit analysis. Alongside immediate economic concerns, a broad understanding of the social and ecosystem services that are part of aquaculture and associated value chains must be considered.

## Introduction

The factors that explain the occurrence and relative importance of aquaculture spatially relate to its historical development based on local demand and suitable agro-ecology and, more recently on a rapid increase in international demand for certain categories of seafood. This latter trend has been accelerated by the continuing deterioration in global fisheries but also by the comparative advantage of consistent quality, supply and price of farmed seafood reaching consumers. Investment, governance and market development also explain the current status. Thus although the specific physical conditions of the Norwegian and Scottish coastlines and fishery

infrastructure predisposed these areas as suitable for salmonid culture, investment in strategic research, legal access to water and land resources and the development of new markets have rapidly transformed small initial enterprises to global entities. It has been suggested that access restrictions and competition with other uses are now one of the key reasons for stagnation of the EU aquaculture sector (Bostock *et al.*, 2009). Shrimp development around the coastlines of Asia and Latin America has also been stimulated by increased demand for these erstwhile luxury products in developed country markets. Here weak governance and dynamic commercial actors (Goss, Burch and Rickson, 2000; Lebel and Anderies, 2006) has resulted in uncoordinated development during the early stages of evolution in these sectors. Attempts by Government to geographically constrain development, for a variety of reasons, have had limited impacts. Experience suggests that major behavioural change has been stimulated by environmental shocks causing major economic loss. Such changes suggest that lessons can be learned and given favourable institutional conditions that sustainability can be progressively improved. The tripartite loch agreements (between the private sector, the state and local communities) have contributed to reduced incidence of salmon disease in mainland Scottish lochs for example.

The development of aquaculture has often been linked to actions and policies outside the immediate sector. Important among these have often been organizations responsible for governance of water and land development. The Water Boards in the People's Republic of Bangladesh (Haque, Little and Murray, 2011), which has had major impacts on the development of the shrimp and prawn industry in the Southwest of the country, and the Kingdom of Thailand that help set the course for development of the Chaopraya Delta as a major aquaculture zone (Molle, 2007) are examples. Such stakeholders with little direct interest in aquaculture have had profound impacts through their actions of its form and function.

External interventions by Government or non-Government organizations to stimulate aquaculture have become a common aspect of broader rural development. These have sometimes been limited to establishing hatcheries to provide a more consistent source of juveniles or to provide more comprehensive services to early adopters but they have generally had a clear geographical focus. Such initiatives in Sub Saharan Africa (SSA) over the last 20–30 years have often been as a result of the aims and objectives of international donor agencies and associated SSA government ministries that have had a poverty alleviation mandate. Many such projects were, and to a certain extent still are, located in rural areas typified by their low household incomes but ignoring other key criteria such as water supply, soil type, topography, access to markets, feed and seed supplies. Very limited development or sustainability has been a frequent outcome.

Both traditional and more recent aquaculture development has tended to occur naturally as concentrated enterprise clusters (Porter, 2001; Little, Nietes-Satapornvanit and Barman, 2007; Ingthamjitr, Phromtong and Little, 1998). In Asia, these were often originally linked to sources of wild juveniles, and/or associated with established research or service centres disseminating knowledge.

The endurance of such clusters of enterprises suggests the benefits of such physical association outweigh the disadvantages of proximity e.g. auto-pollution, pathogen transfer etc. In contrast to the *de facto* zoning in developed economies where aquaculture sites require licences and are subject to planning restrictions, site selection in LIFDCS has typically by-passed official planning mechanisms, where they exist. Official support and/or control is often more likely and effective at the local level; for example in the Socialist Republic of Viet Nam the relative importance of District and commune level planning explains the micro-location of much recent aquaculture. Identification of designated areas for aquaculture are not always the most appropriate; rather areas have been targeted because of their low value for alternative uses or for political reasons linked to broader agendas of decision-makers (Leschen *et al.*, 2005).

Aquaculture site selection on an individual level may reflect a range of different intended outcomes. The excavated pond integrated within a mixed farm may reflect a desire for an on-farm water resource to improve crop irrigation for example as much as a fish culture unit (e.g. Dang *et al.*, 2007) or may be perceived as the heart of a rationale approach to diversification. The potential for such development may be strongly influenced by access to markets; leading to a stronger bias towards intensification in peri-urban locations (Karim *et al.*, 2011).

Urbanisation has often been an important factor in determining the location of traditional aquaculture (Little and Bunting, 2005) but the rapid transformation of rural to urban land use characteristic of many LDCS underlies much of the current dynamics in aquaculture siting. Much of the recent expansion in catfish production in the Federal Republic of Nigeria has occurred close to urban markets rather than in rural locations. The peri-urban vs rural development of aquaculture depends on the transport and communication infrastructure within individual countries and is increasingly facilitated by the use of mobile phone technology. Ha Noi, the capital of the Socialist Republic of Viet Nam, had well defined and managed peri-urban production of both fish and aquatic plants within 4 km of the city centre until very recently (Edwards, 2010), based largely on urban waste wastewater. With recent rapid urban population growth and spiralling urban land values, these urban production sites have steadily declined. Increasingly Ha Noi's growing population is supplied with farmed fish from neighbouring Hai Duong and Ha Tay provinces, with good arterial road links to the capital. In the 1990s with the arrival of "Doi Moi" and the opening up of the economy the Vietnamese government identified these provinces as having the water, land and human resources necessary for developing pond based culture and have since offered support in terms of tax concessions on equipment and inputs, and also the provision of commercial feed and fingerling supplies (Leschen *et al.*, 2005).

The concept of zoning, the purposeful inducement or coercion on the part of Government to ensure development occurs in a certain designated location has its roots in industrial development and is quite contrary to aquaculture emerging as part of an integrated local food production landscape. Such an approach places aquaculture firmly in the realm of technical and research-centric development and towards an industrial, commercial (often export) orientation. It is based on the premise that aquaculture should be supported and isolated from other activities to ensure higher standards, greater efficiencies and reduced externalities (affecting and effected by aquaculture). For example systems can be designed and planned to ensure neutral environmental impacts, rather than having to be problematically and expensively 'retrofitted' later. The concept of science parks within Universities resulting in research spin-outs into mainstream society are long established and it appears that the 'aquaculture parks' concept are following a similar path; the example of NELHA in Hawaii, the home of High Health SPF shrimp, is one example of how such a location can support development at the premium end of the value chain. This may be rather atypical in terms of high tech clustering in a production sector where competition is usually more price/scale than innovation driven (Bostock *et al.*, 2009), a characteristic that also accelerates consolidation trends.

Location with favourable access to high quality water resources is critical. Thus, plans in the Federative Republic of Brazil to implement aquaculture parks around eight reservoirs of the Paranapanema river (Murias, 2010) may on the one hand allow control of environmental impacts *from* aquaculture as well as isolating aquaculture from potential pollutants common in mixed use resources. Conceptually a large part of the value chain can be co-located in the same proximity i.e. hatchery, feed mill, grow-out and processing to reduce costs, enhance traceability and by some measures,

quality. Another example is the emergence of federal state funded “Fish Farming Estates” in peri-urban locations in the Federal Republic of Nigeria where local young entrepreneurs are provided access to key on site services such as water, electricity, drainage, markets access etc to develop concrete tank or pond culture production of the African catfish *Clarias gariepinus* (Umoro, 2012).

The implications for such zoned development on the complex social networks that develop around more conventional aquaculture development are considered later. Framing aquaculture development as a credible activity demarcated by clearly defined geographical and production limits may actually assist in gaining support for access to premium sites. The Blue Archipelago development in Malaysia (Ying, 2009) is one example of this where the case for location *within* a National Park has been negotiated on such a basis. Maintaining pristine water quality will be a requisite for retaining credibility to overseas buyers insisting on high environmental standards, as will ensure broader social benefits to employees and surrounding communities. This contrasts with many previous attempts at zoning that have attempted to exclude aquaculture from coastal areas especially those with intact mangrove areas deemed vital for their provision of environmental and related services. Many such attempts have failed and even where some level of success has been achieved there is little evidence that purposeful zoning to locate or exclude aquaculture has resulted in improved social impacts. More often development is subject to market and other forces that are difficult to manage let alone predict and plan for. A pertinent example is the “peri-urban green zones” established in Ho Chi Minh City, the Socialist Republic of Viet Nam. Although these systems continue to provide considerable employment and produce a significant proportion of the city’s demand for aquatic vegetable they are increasingly under threat from urban developers who continue to encroach into such areas (PAPUSSA, 2004). Similarly the loss of city centre lakes in central Ha Noi that have important recreational, aesthetic and flood control functions in addition to being important sources of fish has required physical exclusion in some cases.

The aquaculture value chain, rather than production alone, needs to be considered within any characterisations of zoning. Thus although shrimp farming now occurs along the coastline in the Kingdom of Thailand, the concentration of processing capacity remains in the upper Gulf of the Kingdom of Thailand, a vestige of the fishery infrastructure and access to ports and major urban centres, in which market intelligence and often consumer demand is concentrated. The global interconnections of value chains have led to losses in processing clusters in Europe to Asian centres where skilful hand work, can be carried out more profitably.

Clearly, the location of aquaculture value chain activities is highly influenced by the people involved and meeting their diverse needs than the outcome of planners and regulators. These are now considered in the section below.

### **Location, location, location – the nature of the farming enterprise and defining the farm**

The specific requirements of farming aquatic animals and the rapid social dynamic in which aquaculture has, and continues to develop necessitates a broad view of what the enterprise is and how it impacts those involved in production and indirectly.

Assuming adequate water supply and appropriate terrain for construction of production facilities, farmers may have many criteria for the specific location of their systems. Fish ‘farms’ are extremely heterogeneous and may not be ‘easy to locate and identify’, nor may ‘local effects be easy to assess’ as claimed (FAO, 2010). Also, of course, the term ‘fish farm’ does not adequately encompass most definitions of aquaculture. Edible aquatic plants of different types, for example, have distinct and specific criteria for siting. Aquaculture can be practiced either as a specialized enterprise

or one integrated with a range of other activities. Full life cycle production may occur on single or multiple sites under a large range of ownership and access arrangements. Producers may live on the farm, for part or all of the year and culture cycles may be year-round or intermittent in view of resource availability or other livelihood priorities. Site selection may be more related to access to alternate employment or markets than predictable water supply or soil retention characteristics of soils.

Water may only be seasonally or ephemerally available and production units can be sited to optimize capture of rainfall, run-off or its retention into the low rainfall months. Aquaculture can be located within watersheds in which upstream and downstream control of water and nutrient flows is limited or it may be dependent on limited groundwater or intermittent supply from centralised storage. With the advent and advance of recirculation technologies more self-contained aquaculture production can be located fairly independently of water supplies in, or on the outskirts of, urban and other water limited contexts. Such systems have the potential, usually at significant energy cost, to use water very efficiently (Verdegem, Bosma and Verreth, 2006). Aquaculture may also be a minor component of a mixed food production system, occurring within, or proximal to other crops and often with porous boundaries. Fish production within or close to ricefields or horticulture treated with pesticides is an example of a potential conflict. Ponds located downstream within watersheds may lose stock through upstream migration into a neighbour's system and/or mortalities associated with contaminated irrigation drainage from neighbours upstream. Producers may be only a small minority of households within the community but aquaculture can impact on a much broader cross-section in diverse ways. Households downstream from catfish farms in the Mekong Delta for example have been forced to source alternative drinking water following pollution events (Quach, 2008). Employment in upstream and downstream activities within aquaculture value chains can support more poor livelihoods than through farming directly (Belton, Haque and Little, 2011).

Location of aquaculture may itself be associated with social and economic status. Poorer people are typically located in more marginal agricultural land with poorer soils and water availability; status within a community may be critical for access to waterbodies. Although adoption of, and benefits from, aquaculture has often been linked to the more resource endowed section of rural communities, in some contexts the poor are more likely to be interested. In Northwest Province, Sri Lanka most potential for aquaculture was identified for poor but cohesive groups at the top of watersheds because of its better 'fit' to their livelihoods, resources and aspirations (Murray, 2004). In areas with weak law enforcement, locations that are observable and more defensible from poaching may be given priority. Clearly for many that adopt aquaculture, financial benefits are not the principle or only benefits. In one recent study, poor rice growers in the People's Republic of Bangladesh adopted the breeding and nursing of tilapia in their irrigated ricefields because in so doing they reduced their use of pesticides and increased their harvests of non-stocked fish they could harvest (Haque *et al.*, 2010). Interestingly, establishing the practice in a community tended to reduce use of pesticide overall, even among households not stocking fish (Biswas, 2008). This suggests that aquaculture can stimulate unanticipated change where it is introduced and that governance can occur at many levels as households and communities adapt and change in response to challenges and opportunities. Even where lack of governance and rapid spread of commercial aquaculture has resulted in undoubted short-term damage to the social and environmental fabric of communities, longer term adaptation and sustained benefits are possible. Belton and Little (2008) describe the complex benefits of the shrimp boom in Central Thailand where longer term benefits have been realized through the adaptive response it has triggered in communities and institutions. Also instructive in the case of Thai shrimp has been the resilience that relatively small-holder producers have demonstrated with a range

of corporate and government support. The sustained production of shrimp in the Kingdom of Thailand on relatively small but intensively managed holdings has been possible through a shift to SPF broodstock, more biosecure practices and supportive governance (Lebel *et al.*, 2010). In contrast corporate approaches to shrimp production based on large farms and employed labour have often had a poorer track record; the critical need for motivated and timely husbandry favours the continuance of self-employed labour organization, often manifested as the family farm albeit with stronger upstream and downstream linkages. These trends suggest the continuance of clustered, independently managed enterprises and the challenge of ensuring traceability and more sustainable practices. Vandergeest (2007) chronicles how local government and communities can be more effective at enhancing sustainability than externally imposed certification schemes.

Once established as an important source of foreign revenue, support from Government for the aquaculture sector may be more forthcoming. Various forms of support such as preferential duties on imported feed ingredients, favourable credit arrangements, improved infrastructure and information availability (or incentives for private provision) are examples. Net demand for raw material exports by processors and consumers in developed countries is very high; hence tariff-structures generally reflect low long-term resistance to such interventionism, particularly compared to agricultural sectors.

#### *Global implications*

The nature of global value chains in aquaculture products suggests that site selection criteria for aquaculture requires a global perspective. The concentrations of feed ingredient production from fishmeal and oil in South America and soybean in the Americas provides employment far from their use as feeds and in turn, production of tilapia and pangasius in Asia offers value addition and employment opportunities closer to their site of consumption. The trends to privatise and add value to genetic resources well established in livestock, is building momentum for farmed aquatic species as the success of SPF shrimp in Hawaii to support the Asian shrimp industry demonstrates.

#### *Location myths*

The textbook approach to aquaculture site selection has often been challenged by the reality and typically this relates to the importance, indeed the dominance, of socio-economic factors. A requirement for perennial water, optimal temperature regimes and supportive government are typically identified as key criteria for success. Lack of water as a stimulus for aquaculture development can be observed on a number of levels. The emergence of an arid country (Israel) as a leader in aquaculture through the last decades of the last century reflected a strong cultural attachment to freshwater fish but also focused a need to integrate its production into its water-limited agriculture (Mires, 2000). In well watered areas of high agricultural potential the opportunity costs of land and water are often substantial and can deter investment in a new activity such as aquaculture. Although typically 'fish bowls'-concentrations of highly productive aquaculture -are situated in well watered areas, demand for cultured fish may paradoxically be higher in areas prone to limitations in, or seasonal, water availability. Gregory and Guttman (2002) found greater interest in stocking fish in areas distant from perennial water that tended to have a greater abundance of wild fish.

Optimal temperature regimes can enhance productivity particularly in stenothermal species but there are some surprising success stories for species located well outside their native range. Production of tilapias in Maoming District, Guangdong Province in southern China has soared to be a major global supplier of the fish (producing an estimated 1/12 of the global crop) despite being located well outside the optimal temperature range of 28–32° (Zhang *et al.*, 2011). Ambient temperatures fall well below this range seasonally leading to occasional mass mortalities, a phenomenon not unlike

the occasional crashes in citrus and coffee in Florida and southern Brazil respectively that carry similar types of risk but remain viable and important centres for production of these crops. The other positive factors make up for the occasional mortality and in the case of tilapia, a reduced growing season even in normal years. The success in mainland China was pre-dated by previous advances in Taiwan where approaches to successfully raising tilapias on the edge of the climatic tolerance were developed. These involved modest but important technical modifications such as the use of more temperature tolerant strains (*O. niloticus* X *O. aureus* hybrid) and various overwintering techniques for different life stages. Research in Northern Vietnam, which shares a similar temperature regime, indicated that pond siting and construction in relation to prevailing winds, or use of wind breaks and, deep ponds and/or polytunnels were sufficient to cost effectively maintaining water temperatures above critical levels and ensuring juvenile fish were of a suitable size to survive overwintering (Dan and Little, 2000). Geographical separation of hatchery and grow-out has also occurred;- tilapia seed from optimal hatchery environments further south are now routinely airfreighted to the north at the onset of the growing season. In an African context the Arab Republic of Egypt, by far the continent's largest aquaculture producer, sees growth being restricted to 8–9 months of the year when ambient temperatures are close to optimal for tilapia production. The use of mitigating technical and management practices allow production and sales of 300 000 MT of tilapia throughout 12 months of the year into domestic markets (Radwan, 2011, forthcoming).

Although there are many examples of Governments being supportive of aquaculture development in countries where aquaculture has shown rapid progress e.g. the Kingdom of Thailand and the Socialist Republic of Viet Nam, there are others where progress has occurred despite a prevailing inertia or even antagonism. The antipathy towards tilapias in the Republic of India and the State of West Bengal in particular has not prevented it becoming the most important single species produced in the Kolkatta wetlands for example. Elsewhere frustration with over complex or environmentally stringent regulations or planning has been related to Europe's stagnating aquaculture development (e.g. Bostock *et al.*, 2009) This might also explain why the Republic of South Africa has not yet fully lived up to its considerable potential in developing aquaculture where some perceive over strict environmental legislation, particularly in the fish farm planning stages, has greatly reduced the opportunity for investors and individual entrepreneurs to get on the first rung of the aquaculture ladder. In reality such factors cannot be entirely delinked from many other prevailing factors including a low competitiveness compared to imports from warmer climes and high opportunity costs of location in coastal areas valued for tourism and other uses.

### **Gaps in the ecosystem approach to aquaculture (EAA) from a social and economic perspective**

Identifying gaps in the ecosystem approach to aquaculture as a strategy from a social and economic perspective requires reflection of the process as much as the activities themselves. The following contributions demonstrate how continued effort is required to try and ensure this process contains enough self-critical reflexivity.

#### *Participatory approaches*

The purpose and intent to incorporate participatory approaches into EAA are positive but careful consideration must be given to who is encouraged and supported to participate, in what ways and for what specific purpose. Since participation has become an accepted orthodoxy in development circles and attracted both mainstreaming and inevitable criticism (see Henkel and Stirrat, 2001), greater reflection is required. Increasingly so-called participation is part of a box-ticking exercise within more blueprint approaches to development familiar in the past. Community stakeholder

engagement is frequently cursory, unrepresentative of marginal voices and more consultative than collegiate. Often, expectations within 'projects' are too narrowly sectoral involving a tiny proportion of potential stakeholders in any active way. Boundary setting and identification of stakeholders have rightly been identified as key steps. The boundaries around EAA are typically set too narrowly and the resources applied too limited and/or conservatively, for what are complex *human* systems.

The separateness of socio-economic well-being and 'ability to achieve' appears to disregard the importance of informal groups and institutions existing in complex real-world settings of legal pluralism. Collective self-organization of producers has been a common response to shared needs and not always related to more formal attempts at promoting producer associations, clubs and co-operatives based on outside incentives. Externally driven organizations have often failed because of underlying weak motivations of participants and/or objectives with unclear or unrealizable expectations. The capacity to offer goods and/or services required by, and affordable to, any group is critical. The governance of successful groups also depends on how power relations are managed internally and with external actors. Relatively few such entities have survived in Africa despite governments and donors alike promoting them. Positive examples within Africa where both governments and developmental NGOs have learnt from previous mistakes in terms of group seaweed cultivation in Tanzania (Msuya, 2010) and the development of small to mid scale commercial fish farmers in Uganda (Walakiri and Leschen, 2011). Unfortunately analyses of the performance of such groups are few and far between (Little, 2010) and there is much to learn about their developmental impacts for members and non-members alike.

Capacity to achieve should consider culture in addition to governance and institutional issue, since the former often underlie the latter and indeed can be predisposing of certain outcomes. Thus attempts, for example, to promote cage culture among a specific marginalised group (women, an ethnic minority etc) through local NGOs should assess the likely role of such actors in effecting sustained change and incorporate mechanisms to deal with strong cultural norms on the likely long term outcomes of such initiatives. Efforts to initiate EAA should also be subject to assessment of cost benefit analysis. Given limiting resources, does the EAA promoted offer better livelihood outcomes than alternative forms of diversification, for example? Is the improved management of local fisheries a more equitable approach to supplying fish to those most dependent? Are aquatic animals from EAA the optimal source of animal source products to support local food security or should efforts be made to support alternatives such small livestock, dairying etc.

Setting boundaries for 'sustainable carrying capacities' should reflect the emerging and dynamic social relationships that surround them. Thus, the extent to which Integrated multi-trophic aquaculture (IMTA and integrated practices more generally occur within the same enterprise and are managed by the same people or between different enterprises and different people can be critical; the example of the pond operator who leases the pond bank to another for vegetable cropping is an example of this. Integration can be an outcome of both passive or active cooperation; the aquatic vegetable grower in Ho Chi Minh City, for example, who crops water spinach growing on wastewater channels in contrast to the catfish farmer who directs wastewater into a neighbour's carp pond or rice field. This latter example also demonstrates the linkages between aquaculture and other human activities both of which can be embraced by the concept of integrated farming (Edwards, 1998). Such examples also suggest the importance of reviewing aquaculture location issues in temporal as well as spatial terms. Aquatic vegetable production in Boeung Cheng Ek, Phnom Penh and the Kingdom of Cambodia is highly seasonal in terms of employment, drawing migrant labour from rural areas outside of the main rice growing seasons and highlighting the strong rural: urban linkages that characterise such activities. The outputs moreover

are particularly important to poorer consumers (PAPUSSA, 2004) and the system provides an environmental service i.e. an effective biological treatment of 80 percent of the city's urban waste water – that benefits a much larger group of stakeholders that remain unaware of its role in sanitation and support to public health. Such systems together with the development of IMTA involving co-location of caged finfish, bivalves and seaweeds share a need to assess social and economic benefits across the value chain and social spectrum of stakeholders impacted. There is a need for quality, quantity and time (QQT) attributes to be incorporated into indicators of EAA impact that reach well beyond the farm and the direct producer and these are now considered.

### Indicators

The development and use of indicators should ideally be based on a synthesis of top down 'expert' and local 'bottom-up' opinion (Bell and Morse, 2008). Indicators should enable a robust baseline of impacts to be built and be a solid basis for further understanding change over time. While site specific, some indicators are more generic and should also allow some comparison between sites and systems.

*Indicators within the broader producer community* should be ideally monitored over time and/ or matched with otherwise similar communities without aquaculture established as a major activity. These activities would point to the depth and spread of impacts within communities in which aquaculture is established, either through direct participation as producers or indirect or secondary benefits through employment or linkages within the economy. Beyond the net benefits, they also indicate if once established aquaculture supports or detracts from equity within the community.

- Proportion of households within the community that gain some benefit(s) from aquaculture during the year-evidence for complementarity within the livelihood portfolio
- Trend of increasing median incomes of all households in the community where aquaculture is practiced
- Low SE of the mean for monthly household incomes in aquaculture communities
- Increasing trend in day labour rate (both in aquaculture and non-aquaculture related activities (Faruque, 2007).

*Indicators for households accessing and managing aquatic systems* would aim to assess the proportion of households that benefit as producers (how equitable or polarized production is) and how resilient the systems are in terms of ecology and social economics. The prevalence and rationale for polyculture at production unit and/or community level is an indicator of both ecological and economic resilience and, because it results in different levels of by-products being generated, likely high benefits for poorer people as employees and consumers. Similarly evidence for water and nutrient-reuse locally is likely to be a useful indicator of resilience. Switching of species indicates again a capacity for change in the face of adverse economic and/environmental shocks (such as small-scale farmers in the Mekong Delta changing from pangasius to other species; Loc *et al.*, 2010). The proportion of farming households that invest in significant stock protection, the level and means of which needs to be locally contextualized, could signal the level of on-going social conflict related to aquaculture development. Many of these indicators are evidence for adaptive learning at the household and community level.

- Proportion of households within the community attempting some aspects of aquaculture-stocking of seed –indicative of impending need for food security or overcoming temporal shortages (seasonal and/or year on year)
- Producer households demonstrating some form of adaptive management of their managed aquatic system to mitigate flood/drought risks
- Number of benefits expressed by households from adoption of aquaculture (Haque *et al.*, 2010). A large number of benefits perceived by a high proportion of adopters suggest that adoption brings a range of benefits many of which are non-financial

- Number of households with units of production, and low SE of the mean number of units per household
- High species variability within culture systems either as concurrent or rotational polycultures at household and community level
- Variation from average model traced to initial adoption by pioneers
- Evidence for wholesale switching species in response to market signals
- Evidence for water/nutrient reuse from aquaculture systems and values attained for such initiatives (social, nutritional and/or financial)
- Proportion of producers that invest significantly in stock protection and/or lose a significant amount of stock to poaching, predation and/or poison
- Proportion of producer enterprises based on outside investment

*Indicators for producer associations/groups/clubs* which are increasingly recognized as critical assets to support common action and social learning but for which governance and inclusion are issues

- Trends in exclusions from and conflicts within producer associations
- Evidence for sustainable rules, transfers of responsibilities, transparent procedures
- Independence from outsiders and subsidies
- Demonstrated participation by women, minorities and normally marginalized groups

Indicators for poverty impact of aquaculture

- Decline in relative price of fish over last five years
- Proportion of fish sold in the community sourced from local aquaculture as an indicator of multiplier effects
- Evidence for increase in number of meals including fish increasing among the poorest groups in the community since aquaculture established
- If irrigation function of ponds support horticulture evidence for greater, more consistent consumption among poor groups of fresh vegetables derived from such systems
- Do we see a decline in equity over time after introduction/establishment of aquaculture in a given context (*Aquaculture-related Gini index?*)
- Evidence for increases in number and density of activity nodes within ‘actor networks’; trends towards spread from immediate kin to distant and non-relatives (specific to cultural context)
- Evidence (longer term) for aquaculture supporting escape from poverty and/or preventing decline into poverty (Krishna, 2007; Belton, Haque and Little 2012)
- Intergenerational welfare indicators

### Summary

The location of aquaculture activities has historically been based on a combination on local demand and agro-ecology, with global demand and deteriorating capture fishery stocks having an increasing influence. External interventions aimed at stimulating aquaculture in developing countries have often been driven by objectives and geographical boundaries without paying enough attention to other key criteria for successful aquaculture, often resulting in limited development and sustainability. Meanwhile, established and developing aquaculture sectors have been seen to ‘cluster’ around important resources or services, to greater effect. Site selection in un-planned clusters is based on factors beyond basic resources and services required; proximity to markets is a key driver for peri-urban production for example. Transport links are important in creating options and greater production efficiencies in commercial farms. Aquaculture has been seen to flourish away from ideal production environments, such as in Israel where water resources are scarce, and tilapia production in the People’s Republic of China where water temperatures are well outside the optimal range. Attempts to restrict certain types of aquaculture or limit them within zones have often failed, especially in countries with weak governance. Factors specific to local natural,

social and economic environments can be major drivers in aquaculture. Aquaculture has potential to exert significant social and economic impacts through upstream and downstream links around the use of chemicals, wastes expelled and stock migration. This incorporates a broad section of people as stakeholders in the broader system. Similarly, employment along the value chains, both upstream and downstream, bring benefits to many not involved in farming directly.

Focus in development programs should be placed on identifying and responding to local factors, rather than allowing top-down, external factors to dominate. Community stakeholder engagement needs to be strengthened, with more rigorous application of cost benefit analysis. Alongside immediate economic concerns, a broad understanding of the social and ecosystem services that are part of aquaculture and associated value chains must be considered. Identification and use of appropriate indicators can be a robust approach to assessing impacts, and must pay equal attention to local conditions and opinion if they are to be accurate and relevant in their application.

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