

Carrying capacity and site selection tools for use in the implementation of an ecosystem-based approach to aquaculture in Canada: a case study

Stephen F. Cross

Associate Professor/Director – Coastal Aquaculture Research and Training (CART) Network, University of Victoria, Canada

Cross, S. 2013. Carrying capacity and site selection tools for use in the implementation of an ecosystem-based approach to aquaculture in Canada: a case study. *In* L.G. Ross, T.C. Telfer, L. Falconer, D. Soto & J. Aguilar-Manjarrez, eds. *Site selection and carrying capacities for inland and coastal aquaculture*, pp. 253–262. FAO/Institute of Aquaculture, University of Stirling, Expert Workshop, 6–8 December 2010. Stirling, the United Kingdom of Great Britain and Northern Ireland. FAO Fisheries and Aquaculture Proceedings No. 21. Rome, FAO. 282 pp.

Abstract

Coastal British Columbia, Canada is employed in a *case study* of aquaculture carrying capacity issues – illustrating how this jurisdiction currently manages aquaculture site selection and operations, and how ongoing changes to its overarching policy and regulatory processes relate to the development of an ecosystem-based approach to aquaculture in this jurisdiction. Environmentally, carrying capacity issues are addressed using a combination of GIS-based resource mapping and spatial separation guidelines, DEPOMOD simulations of organic waste dispersion/accumulation, and performance-based monitoring using physical-chemical surrogates of biological response to ecosystem stress. The environmental tools for carrying capacity and site selection are not applied equally to all aquaculture sectors and deficiencies in the approach are recognized as significant gaps to forming a comprehensive, and defensible ecosystem approach to aquaculture (EAA). Socially, British Columbia aquaculture competes with a variety of coastal stakeholders, and the issues and interactions among these stakeholders are considered and integrated into the management (siting, carrying capacity, operating) framework of this social-ecological system. New initiatives to assess social-ecological performance, in the form of a Sustainability Report, has been introduced and holds promise of communicating the positive attributes of an ecosystem approach to aquaculture. Recommendations for transitioning British Columbia aquaculture to an EAA model include: (i) ensuring an appropriate geographic definition of the ecosystem boundaries; (ii) establishment of quantifiable goals and objectives for the EAA; (iii) use of quantitative indicators/metrics to cover all of the social-ecological attributes of the system; (iv) include results generated from these metrics to develop Performance information; (v) ensure effective communication among agencies and the public; and (vi) encouraging innovation through performance incentives.

Introduction

The global pressures on wild fisheries resources, exacerbated with the significant and increasing demand for seafood, has stimulated a spectrum of growth and innovation within the worldwide aquaculture industry. Canada, which supports the world's longest coastline, largest freshwater system, greatest tidal range, and most diverse coastal physiography, would appear well positioned to meet the challenges of increasing the global seafood demand through the expansion of aquaculture. However, in recognizing the inherent need to adequately balance the environmental and socio-economic carrying capacity factors that can ensure sustainable aquaculture development, Canada is in its current, complex position of self-analysis and regulatory/governance reform.

This document uses the Canadian situation, and coastal British Columbia in particular, in a *case study* of aquaculture carrying capacity issues – illustrating how this jurisdiction currently manages aquaculture site selection and operations, and how ongoing changes to its overarching policy and regulatory processes relate to the development of an ecosystem-based approach to aquaculture in this jurisdiction.

Why British Columbia?

There are a number of reasons why one would choose the west coast of Canada – British Columbia – for this *case study* exercise. Despite its globally-recognized reputation with respect to social-environmental conflict, this western region's aquaculture production (and associated economic value) is the largest in the nation. Export of over 85 percent of British Columbia (as with all of Canada's) production occurs to the United States, and hence market-driven change to aquaculture "acceptance", as an important social-ecological food production system, will truly reflect a North American perspective on the future of sustainable aquaculture in this hemisphere.

From a physical perspective the coastline of British Columbia is highly complex, represented by over 25 725 km of coast, shallow to deep inlets (fjords), high and low energy tidal passages, and more than 40 000 islands (of various sizes) extending from the Washington State to the Alaska border. This cold-water environment, similar to that of the Kingdom of Norway and southern Chile, is extremely rich in habitat and species diversity, many of which continue to support a variety of fisheries – but none alone can supply the growing export demand. It is this diversity of aquatic life that also represents the potential for significant aquaculture growth, with the regional government identifying over 80 local species that could be considered as aquaculture production candidates in the future.

Socially, British Columbia aquaculture is faced with a complex mosaic of coastal stakeholders, and the issues and interactions among these stakeholders are considered and integrated into the management framework of this social-ecological system. The use of Crown Land (government-controlled land and the nearshore aquatic base) include such activities as forestry, mining, recreational and commercial fisheries, tourism, and community development – these and other uses often compete for space through regional planning exercises and/or interact environmentally to exclude other, more sensitive activities from development opportunities.

Inclusion of coastal aboriginals, or First Nations, add yet another layer of complexity to the social-ecological aquaculture systems of British Columbia. This region of Canada supports 25 distinct First Nation peoples with over 100 tribes/bands that have documented territorial claims to a variety of coastal resources – particularly to traditional use of many of the area's valued littoral and shallow sub-littoral species. Consideration of Traditional Ecological Knowledge (TEK) within these coastal communities, historical ceremonial uses, and present day subsistence fisheries represent critical social factors that affect how and where aquaculture can be developed.

With a production environment considered ideal for a wide range of aquaculture species, an extensive coastline that could support significant aquaculture development and expansion, and a complex social net of coastal stakeholders (including the traditional, cultural uses of First Nations), the balance of these social-ecological factors represents both regional (British Columbia) and national determinants for site selection, carrying capacity and sustainable aquaculture development practises in Canada – and in application an Ecosystem-Based Approach to aquaculture.

Regulatory and governance framework

The primary responsibility for Canadian aquaculture management is shared between regional (Provincial) and national (Federal) levels of government. Recently (December/2010) the regulation and licensing of aquaculture activities (finfish and shellfish) has been transferred completely to the Federal government – led by the Department of Fisheries and Oceans (DFO) – while the Province of British Columbia maintains control and responsibility of the Crown Land allocation for coastal aquaculture. A new Canada–British Columbia Memorandum of Understanding (MOU) with respect to aquaculture is being negotiated and is expected to layout new roles and responsibilities for each of the parties.

The *siting application* for a new aquaculture tenure (lease) is a proponent-driven process in British Columbia. The aquaculture proponent identifies a potential farm site that is suitable for the species being considered for the development, identifies potential and local stakeholder conflicts associated with the proposed location, and then (if direct consultation with stakeholders resolves any identified conflicts) completes a detailed biophysical appraisal of the proposed farm site, listing and discussing all impacts associated with the proposed level of production, the configuration and orientation of farm infrastructure, the operational risks and emergence response plans, and specific management practises for all activities.

The application for an aquaculture site comprises a standard format and a comprehensive list of information requirements (see following section on Decision Support Tools – Site Specific Management) that jointly form a *Management Plan* for the proposed operation, and the basis for the subsequent review and adjudication. This information typically includes a variety of maps (GIS) delimiting and overlaying the proposed infrastructure works in relation to local aquatic resources and sensitive habitats, wildlife use, adjacent stakeholder activities (aquatic and upland), projected spatial and temporal operational impacts (determined through model projections), site physiography, oceanographic conditions and seasonal water quality, etc.

Aquaculture site tenure/Lease allocation

The completed *Management Plan* developed for a new aquaculture facility is submitted to the Provincial (regional) government for review and ultimate approval. Ensuring that all required information is contained in the application, the packages are then referred out to all potentially affected stakeholders for comment and identification of outstanding issues/concerns – local/regional/federal government agencies, local industry sectors and/or businesses (including adjacent aquaculturalists), local communities and First Nations, and the general public (through media notifications). All parties are given a period of time to respond with their comments/concerns which are then dealt with by the proponent – addressing the issue(s), satisfying the respondent if possible, and reporting the outcomes back to Provincial Lands office.

A key Federal role in the Site application process occurs as part of the above referral process. Under the Canadian Environmental Assessment Act (CEAA) each new farm site application is usually reviewed with respect to all positive and negative environmental, and socio-economic consequences associated with the proposed development. The ‘triggered’ CEAA is coordinated by the Responsible Authority

(RA), which is typically Transport Canada (triggered by concerns under the Navigable Waters Protection Act – NWPA) or DFO (triggered given the habitat protection provisions under the Federal Fisheries Act).

Results of the CEAA screening are forwarded to the Province and support issuance of a Crown Land tenure/lease or, alternatively, document why the farm site application should be denied. This key federal referral response, as well as those received from all other stakeholders, are considered in the tenure issuance process. If a positive outcome the Province issues the Aquatic Land tenure (lease) – for the specified purpose only – for a period ranging from 5–25 years (renewable).

Operational regulations

In 2009, the British Columbia Supreme Court released a decision finding that “finfish aquaculture” is a “fishery,” and thus falls within the exclusive jurisdiction of Canadian Parliament under subsection 91(12) of the *Constitution Act, 1867*. As a result, it ruled that the majority of the provisions of the existing provincial aquaculture legislation lie outside the constitutional jurisdiction of the province, including those pertaining to fish, shellfish and all other invertebrates – marine plants were exempted from the ruling.

In considering and developing a new regulatory regime under the federal Fisheries Act, which was ruled by the Court to be in place by 18 December 2010 (completing the transition from Provincial to Federal jurisdiction), the Canadian government has considered the importance of covering a number of elements which would otherwise be missing as a result of this ruling: (i) aquaculture licensing for the purposes of regulating the sector; (ii) farmed fish containment issues; (iii) fish health and sea lice management; (iv) waste management, as it applies to protection of fish and fish habitat; and the (v) release and deposit of deleterious substances.

The proposed Regulations (currently under final review before implementation), together with applicable provisions of existing federal regulations, are anticipated to create a regulatory regime that will ensure the proper management of aquaculture, particularly with respect to protection and conservation of fish and fish habitat (an ecosystem approach), in an open and transparent manner. “Management plans and supporting operational policies and guidelines, greater visibility of compliance efforts, increased public reporting of compliance and environmental performance data, and commitment to improving environmental performance will be expected to contribute to improved public confidence in the sector”.

Supporting the implementation of the new DFO regulatory regime, there will be program policies and Integrated Management of Aquaculture Plans (IMAPs), modelled after the Integrated Fisheries Management Plans currently used by DFO in other fisheries. The IMAPs will publicly document management objectives for each major sector (e.g. finfish, shellfish), and identify specific operational directives and other matters as appropriate for the management of the sector. DFO proposes to develop IMAPs at the *area level* for key species (such as salmon) to support consideration of cumulative impacts. The IMAPs will eventually be used to set detailed license conditions. IMAPs and operational directives will be consistent with national guidelines, respect other national and regional departmental priorities, and will integrate advice from stakeholders.

The new Aquaculture License will consolidate a number of previously ‘permitted’ activities, providing some level of increased management efficiency. Each license will identify culture species and be accompanied by site-specific conditions with additions of the license that would be imposed. The conditions will include: (i) measures to minimize escapes, introductions and transfers, incidental catch, predator control, impacts to fish and fish habitat, fish health, sea lice, etc.; (ii) monitoring requirements; and (iii) record keeping, notification and reporting.

Problems and Constraints

While the developing regulatory framework for aquaculture in western Canada, in its application, has access to much of the social and ecological information required to support an ecosystem-based management approach, primary responsibility and governance of this aquatic food sector as a *fishery* rather than a farming activity may lead to a suite of potential conflicts of interest, inefficiencies, and possible judicial challenges. Development of legislation specific to aquaculture (e.g. an Aquaculture Act) may alleviate many of these governance issues, and like other countries that have adapted this approach, allow for the integration of appropriate siting and operational factors into a consolidated and comprehensive approach for managing a socio-economic and environmentally sustainable industry.

Decision support tools

Aquaculture site selection, review and approval in British Columbia is supported with tools that comprise a combination of coastal resource information databases and detailed site-specific assessment and evaluation. The combination of these approaches is intended to address coastal zone management issues (resource allocation) as well as providing criteria (and guidelines) for satisfying concerns over carrying capacity – cumulative impacts of the sector development.

Coastal zone management and aquaculture site selection

British Columbia has been collecting coastal resource information/data in a systematic and synoptic manner since 1979. The resource data collected is quality controlled by a peer-reviewed provincial Resource Information Standards Committee, using standards developed specifically for data management and analysis. The British Columbia Coastal Resource Information System (CRIS) is an Internet-based interactive map for viewing coastal and marine data. A wide variety of coast and marine resources are included, such as aquaculture, shoreline classification, habitat and selected fisheries information, and key human use attributes. The currently available map CRIS information is presented (Box 1).

Much of the provincial coastal resource (CRIS) data are freely accessible and can be viewed or downloaded from a general user perspective or from that of a GIS user, the latter including appropriate formatting for integration into specific mapping applications. See the following web portal: <http://webmaps.gov.bc.ca/imf5/imf.jsp?site=dsscoastal>. Access to these data, by an aquaculture proponent, are used in an initial screening sense to facilitate the site selection process – identifying local stakeholders, sensitive habitats or other potential social or ecological conflicts that may preclude the siting and subsequent operation of an aquaculture facility in a proposed location.

Development of the British Columbia Coastal Resource Information System is ongoing. The application provides access to data currently held on Land and Resource Data Warehouse (LRDW). As additional layers are added to the LRDW, subsequent releases of the application include these additional layers and further enhancements. One such layer, specific to aquaculture, comprises the broad scale evaluation of shellfish aquaculture capability. Initiated by the Province in the mid 1990's this initiative, completed over a five-year period, assessed all of the intertidal and subtidal area in terms of the biophysical conditions that determine the ability of an area to successfully support various species and approaches of culture, i.e. deepwater oyster and scallop culture, and intertidal (beach) culture of oysters or clams.

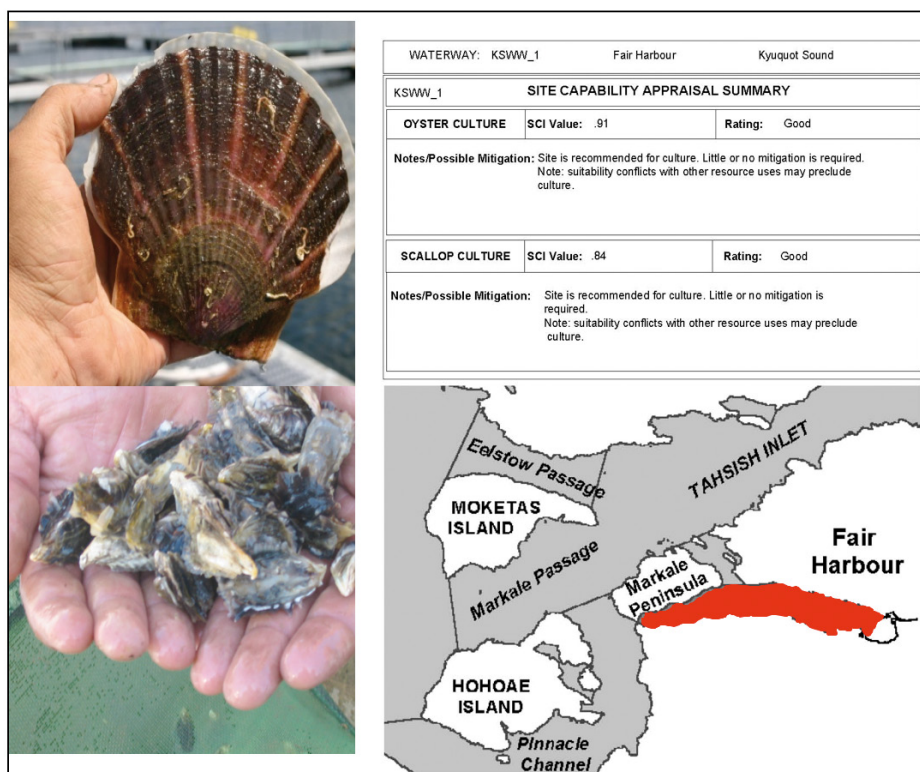
A Shellfish Capability Index (SCI) was developed (Cross and Kingzett, 1992) to integrate the various biophysical parameters in a weighted species model of projected site culture capability performance. Extensive field surveys, conducted during seasonal extremes (winter and summer periods), were used to acquire basic biophysical information on all beaches and waterways of the province. The SCI model was then

BOX 1	
Available data in CRIS, the British Columbia Coastal Resource Information System- Coastal Data Index. (January 2011)	
<p>AQUACULTURE Fresh water aquaculture farms Marine finfish aquaculture farms Salmon aquaculture suitability rating Seafood processors Shellfish aquaculture capability Shellfish aquaculture farms Shellfish hatcheries</p> <p>BIOPHYSICAL SHORELINE CLASSIFICATION Biophysical shoreline</p> <p>BIRD HABITAT Alcids Bald Eagles Black oystercatchers Cormorants Dabbling Ducks Diving Ducks Fulmars, shearwaters and petrels Geese and swans Great blue heron Gulls Loons and grebes Shorebirds Pelagic birds (unspecified) Water fowl (unspecified) Bird colonies/nesting sites (excluding Bald eagles)</p> <p>FISHERIES, COMMERCIAL Anchovy Crab Geoduck Goose binnacle Ground fish Herring food and bait Herring rose Octopus Prawn Salmon (net) Salmon (trawl) Scallop Sea cucumber Shrimp Squid Red and green sea urchin</p> <p>FISHERIES, RECREATIONAL Crab Finfish (includes sport salmon) Groundfish Prawn Scallop Squid</p> <p>FISHERIES, OTHER Clam beaches Herring spawning segments Salmon and herring holding areas</p>	<p>MARINE ECOSYSTEM CLASSIFICATION Marine ecoregions Benthic ecoregions Pelagic ecoregions</p> <p>MARINE MAMMALS California sea lion distribution Dall's porpoise distribution Gray whale (migrating and resident) distribution Harbour porpoise distribution Harbour seal distribution Humpback whale distribution Killer whale distribution Northern fur seal distribution Pacific white sided dolphin distribution Sea otter distribution Californian and steller sea lion haulout areas Sealion rafting areas Steller sea lion distribution</p> <p>MARINE PLANTS Eelgrass distribution Kelp distribution</p> <p>OFFSHORE OIL AND GAS Aeromagnetic Climate stations Cruiseship routes Explorations potential Exploratory well's Gravity Oil and gas tenure – Provincial Oil and gas tenure – Federal Sedimentary basins Sponge reefs Tanker exclusion Territorial (200 mile) limit Bedrock Faults Grid blocks Seismic lines Basins</p> <p>HUMAN USE Airports Anchorages BC Ferry terminals Boat cruising routes Boat launches Campsites Diving sites Marine Industries Kayak route destination points Marinas Marine hazard points Marine hazard lines Moorages Navigations aids Kayaking routes</p>
<p>Source: CRIS, the British Columbia Coastal Resource Information System- Coastal Data Index. (January 2011).</p>	

applied coast-wide to provide a general overview as to what specific areas might be best suited to shellfish aquaculture – but solely from a biophysical perspective. Nevertheless, this type of tool provides an important spatial addition to the coastal zone management database inventory and assists both proponents and government regulators that are charged with Management Plan reviews for new aquaculture sites.

Figure 1 illustrates the results for a location (Fair Harbour, shown in red) in which a proponent might be interested in developing a scallop farm. Based on the survey the SCI was calculated as 0.84 and the area is rated as *Good*. While indicating that the area is considered highly capable of growing scallops, the associated note also makes it clear that this activity must also be considered with respect to other stakeholder activities.

FIGURE 1
 Example of shellfish (oysters, scallops) deepwater aquaculture capability appraisal for Fair Harbour, west coast of Vancouver Island, British Columbia, Canada



Note: Entire coast completed for both intertidal (beach) and deepwater shellfish opportunities and maintained as part of the Provincial Coastal Resource Information System with GIS maps is accessible to all proponents.

Source: CRIS, the British Columbia Coastal Resource Information System- Coastal Data Index. (January 2011).

Given the extensive area of coastal British Columbia that is capable of supporting aquaculture, yet remains undeveloped in this regard, the issue of aquaculture carrying capacity – at least in terms of multiple farm site effects – are recognized but are a lower priority. However, government has established guidelines for spatial separation for finfish farm operations, applied to address the potential issues of disease transfer, sea lice interactions along migratory routes of wild salmon, and cumulative nutrification impacts. Similar spatial separation has not been considered for shellfish operations, although concentrated development of shellfish in two coastal regions have resulted in site-specific research projects into ecosystem effects (primary productivity impacts) given the intensification of shellfish production – no negative effects were documented in these situations.

Site-Specific Evaluation

While the evaluation of aquaculture operations in terms of carrying capacity are not explicitly implemented within the farm siting process in British Columbia, the production-related review does incorporate considerable detail with respect to site operational effects related to farm size (production levels), farmed species, infrastructure configuration/orientation with respect to oceanographic patterns, site physiography, etc. Farm siting must not have a negative impact to fish or fish habitat, as specified in the habitat provisions of the Canadian Fisheries Act, and specific infrastructure siting and operational guidelines have been established (and are under modification/review under the new regulations).

The proximity to sensitive and/or critical fish and fish habitat, and the dispersion and accumulation of wastes generated from an aquaculture facility, are the two key issues considered in the site-specific evaluation for initial siting and ongoing operational monitoring of aquaculture facilities, respectively. Detailed habitat (biophysical) surveys are required prior to site installation to clearly delimit the spatial extent of all littoral and sublittoral attributes of a proposed farm site, i.e. bathymetry, substrate composition, biological community structure, and oceanographic characteristics. Subsurface attributes are typically documented using remote operated vehicles (ROV's) and/or divers. Tidal activity of a site is determined through deployed current meters (2–3 meters over a lunar cycle) and an optional circulation survey.

All of the information acquired prior to a farm site installation are geo-referenced and integrated into a site map (GIS) showing proposed infrastructure position with respect to all of these biophysical data as well as the archived social (stakeholder) information (e.g. CRIS data). None of the infrastructure associated with an aquaculture operation (shellfish or finfish) can be positioned over any valued ecosystem component (e.g. critical or sensitive habitats such as eelgrass beds, kelp forests, fish spawning grounds, bivalve beds, corals, sponge complexes, etc.).

In the case of finfish farms, where required feed inputs to the system are associated with significant levels of organic waste discharge, DEPOMOD model (Cromey, Nickell and Black, 2002) runs using the site acquired oceanographic, bathymetric and proposed production information are completed under average and maximum feed input scenarios to predict spatial patterns of waste deposition around the farm facility. Regulatory guidelines currently require that no predicted deposition $>2.0\text{g C/m}^2/\text{day}$ occur inshore of the 30-meter depth contour to avoid all potential impacts with shallow subtidal communities, and that predicted levels $>5.0\text{g C/m}^2/\text{day}$ not persist at any location beneath or in the immediate vicinity of the farm itself.

Operational monitoring requirements

In addition to fully supporting all forms of Best Management Practises (BMP's), a structured environmental monitoring program is a regulatory requirement of all finfish farms in coastal British Columbia – there is no similar application in the shellfish sector. The finfish program is Performance Based, and focused on environmental loading of organic wastes generated from the farm. The benthic monitoring requires that physical-chemical surrogates of biological response (i.e. sediment sulfides, REDOX) remain below specified performance thresholds prior to fish entry to the farm, and again (at a secondary performance threshold) during the period of peak biomass within the farm system.

The application of a performance-based approach to environmental monitoring and regulatory compliance provides an inherent incentive for production innovation – devising approaches to ensure compliance is achieved while maintaining or increasing farm productivity. For example, one British Columbia company has achieved commercial status for its integrated multi-trophic aquaculture (IMTA) system – an ecosystem approach to aquaculture system design – and is currently operating to reduce the environmental effects of discharged organic and inorganic wastes while increasing its profitability through its multi-species sales (see www.SEAvisiongroup.ca).

Sustainability reporting

Until very recently, the focus on 'sustainability' has been one that has dealt almost exclusively with environmental performance. In Canada, with the recent shift to a federal lead regulatory agency, recognition of the combined social-ecological attributes of aquaculture has resulted in the development of a Sustainability Reporting initiative that has garnered support from a number of industry associations.

Objective: To demonstrate aquaculture sustainability with regard to economic, social, and environmental performance, and to engage Canadians in addressing the sustainability concerns.

Coverage: Use of multiple sustainability indicators (economic, HR, food safety, environmental) – potentially more than 22 specific metrics (license, production, value, compliance, value added proportion, employment, exports, traceability, therapeutic use, BMP, FCR, disease, certification, etc.)

Reporting Frequency: Annual – every spring beginning from 2010

Reporting Agencies: DFO and Statistics Canada

Gap analysis

While not explicitly referring to the aquaculture Siting and Carrying Capacity evaluations as an Ecosystem-Based Approach, the British Columbia process does ensure that these components of sustainability are addressed and that they in fact comprise many of the attributes of these complex social-ecological systems. Weaknesses, or gaps, in this Canadian process can be assessed independently – addressing ecological (production-related) siting and carrying capacity issues, and also the social aspects.

Ecological-related carrying capacity

Although farm siting in British Columbia provides the proponent and regulator with access to a broad range of databases and information on stakeholder and resource use, and provides limited guidelines on spatial separation between fish farms (only) and from sensitive or critical habitat, there is no objective process in place to assess the cumulative consequences of these multiple activities and the effect of including any new development into the system. An effective assessment of carrying capacity, and one that supports a goal of ecosystem-based management should be inclusive of all coastal activities and the potential cumulative effects of their coexistence in an area.

Use of DEPOMOD to predict the spatial extent of organic waste discharge, and the potential interaction with the biophysical environment is applied to finfish farms, and focuses on settleable material only. The effects of deposition from suspended shellfish facilities are also relevant and the dissolved nutrient (inorganic nitrogen) losses from aquaculture should also be assessed in the context of carrying capacity.

Performance Based monitoring metrics, designed to ensure aquaculture operations have limited spatial and temporal effects (impacts) on the receiving environment, are again focused on the localized benthic response and are employed for finfish sector only. The extent of water quality effects and the potential for cumulative impacts are missing from ongoing assessments.

Social-related carrying capacity

The recognition that socio-economic factors play an important role in the development of sustainable aquaculture has grown steadily over the past decade. Inclusion of open public consultation, and consideration of all stakeholder activities and potential operational conflicts, are a routine part of the farm siting process in coastal British Columbia. A critical weakness in this process is in how the values and experience (traditional ecological knowledge) of First Nation peoples can and should be integrated into the farm siting and carrying capacity assessment process. These groups remain intimately connected to the coast – many still residing in remote communities, reliant upon resource-based livelihoods – yet they are often marginalized when it comes to resource allocation and development-related decision-making. An approach for aboriginal participation in the social-ecological aquaculture system would strengthen the transition to an ecosystem-based aquaculture approach.

The development of an industry *Sustainability Report* provides a positive approach to quantifying industry performance, and hence moves to address the social license

issues that have historically hindered aquaculture development in coastal British Columbia. Addressing not only the environmental performance of the industry, this type of initiative can illustrate the significant socio-economic impacts associated with a sustainable aquaculture industry. Current problems in the development of such performance indicators include the limited nationwide statistics on aquaculture, the comparability of data among government agencies (as well as accessibility), and the inherent difficulty in meeting the demands of the public, eNGOs, and the media.

Recommendations

“An ecosystem approach for aquaculture (EAA) is a strategy for the integration of the activity within the wider ecosystem in such a way that it promotes sustainable development, equity, and resilience of interlinked social and ecological systems”. Soto *et.al.*, 2007

The British Columbia case study would suggest that many of the pieces required of an ecosystem approach for aquaculture are in place but are perhaps not yet integrated into a process that recognizes it as such, or one that is actively making the changes required to meet the broader goals of such an approach. In moving forward and taking the initiative to facilitate the development of the ecosystem approach to aquaculture (EAA), it is recommended that five key issues be concurrently addressed.

- Define the geographic boundaries of the ecosystem.
- Establish quantifiable goals (long-term) and objectives (short term) for the EAA and include a process to support continual improvement.
- Identify and use specific, quantitative indicators/metrics that represent all of the social-ecological attributes of the system.
- Include environmental, social and economic information to evaluate and report on EAA performance, associated management decisions and options.
- Ensure inter-agency and inter-government cooperation and communication as well as an open public consultation process.
- Encourage industry innovation through the application of performance incentives.

Conclusion

British Columbia is collecting a variety of information in support of an ecosystem-based management framework for aquaculture. Consistent application and integration of these environmental and socio-economic data into the operational stages of a performance-based regulatory model will encourage industry-driven innovation as we strive for globally sustainable seafood production.

References

- Cromey, C.J., Nickell, T.D. & Black, K.D. 2002. DEPOMOD modelling the deposition and biological effects of waste solids from marine cage farms. *Aquaculture*. 214: 211–239.
- Cross, S.F. & Kingzett, B. 1992. *Biophysical Criteria for Shellfish Culture in British Columbia: A Site Capability Evaluation System*. Prepared for the B.C. Ministry of Agriculture, Fisheries and Food. 40 pp. + Append.
- Soto, D., Aguilar-Manjarrez, J., Brugère, C., Angel, D., Bailey, C., Black, K., Edwards, P., Costa-Pierce, B., Chopin, T., Deudero, S., Freeman, S., Hambrey, J., Hishamunda, N., Knowler, D., Silvert, W., Marba, N., Mathe, S., Norambuena, R., Simard, F., Tett, P., Troell, M. & Wainberg, A. 2008. Applying an ecosystem-based approach to aquaculture: principles, scales and some management measures. In D. Soto, J. Aguilar-Manjarrez and N. Hishamunda, eds. *Building an ecosystem approach to aquaculture*. FAO/Universitat de les Illes Balears Expert Workshop. 7–11 May 2007, Palma de Mallorca, Spain. FAO Fisheries and Aquaculture Proceedings. No. 14. Rome, FAO. pp. 15–35. (also available at www.fao.org/docrep/011/i0339e/i0339e00.htm).