Aquaculture Sustainability: Developing Concepts of a Decision Support Tool for Licensing Freshwater Cage Aquaculture in Ontario

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Abstract

Approaches to managing aquaculture's sustainability have traditionally focused on a relatively few, but important, environmental impact parameters. A broader and more contemporary concept of aquaculture sustainability has now evolved to include various other parameters considered relevant to those multiple stakeholder groups who may be affected by the industry and its practices.

Consequently, the lead licensing agency for aquaculture in Ontario initiated a project to establish new 'Harmonized Guidelines' for reviewing a cage-farm site application, in an attempt to develop a 'one-stop' application approach, and improved licensing procedures that can accommodate the needs of multi-stakeholder assessment. A formalized, Decision Support Tool (DST) was developed to incorporate these new guidelines into an objective and transparent decision-making matrix that could be used to aid in the more efficient assessment of an application for either the establishment of a new farm site, or the expansion of an existing farm. The primary objectives for the DST development included: the provision of an 'approved', 'cautionary' or 'refusal' rating system for each section criteria; an overall licensing application analysis; a clear explanation of the decision and rating criteria used; clear indications on how data provided by the applicants is to be assessed; ability to address obvious licence refusal criteria early in the application process; provide documents for each section which have been developed by a multi-agency writing team to support the decision-making rationale; enable easy changes to formulae constants and compliance values as science improves; and finally, to develop the DST tool in an easy to use software application package. Subsequently, a DST was developed that provides 'ratings' for multiple areas such as water quality, operational practices, ecosystem impacts (including species at risk, fish health/habitat/communities), sediment impacts and other user conflict criteria. Specifics for each information section and potential outcomes of the decision analysis approach developed here are detailed in this paper.

Introduction

Until recently, sustainability of the aquaculture industry was a somewhat illusory concept that traditionally was poorly defined and narrowly interpreted to encompass mainly environmental objectives. An 'ecological footprint' methodology that assessed the capacity of a natural system to supply environmental goods and services (Folke, Kautsky and Trell 1997, Tyedmers 1999, Bunting 2001) was typically central to the evaluation of aquaculture sustainability. However, sustainability, after all, implies that a profitable industry must evolve in some sort of delicate harmony within the social, environmental and economic milieu of the community in which it exists (Moccia and Hynes, 1998). This recognition has resulted in significantly more complex decision-making and strategic planning objectives that must be employed to determine the growth rate and geographical distribution of farms in any given ecosystem. Such increased complexity has lead in part, to the use of enhanced decision support systems (or expert systems) to reconcile a variety of facets involved in aquaculture management and regulation. In Ontario, Canada, licensing decisions for cage-aquaculture occur as part of a complex, laborious and time-consuming process; a process reviewed and commented upon by several government agencies and regional interest groups who often have very disparate views about what is, or is not acceptable. This has resulted in a form of 'quiet' moratorium on the issuing of new licences in the Province, and has created a somewhat disabling environment in which the aquaculture industry can manage its development.

In the last half-decade, there have been several attempts to incorporate a broader scope of social and economic measures within models of aquaculture sustainability (Burbridge, Hendrick, Roth and Rosenthal 2001, Caffey, Kazmierczak and Avault 2001, Costa-Pierce 2003, Frankic and Hershner 2003). This is an essential step to ensuring orderly growth of the aquaculture sector through a synergy of ecological sustainability objectives coupled with economic viability goals.

An expanded definition of aquaculture sustainability necessarily results in increased complexity in the decision analysis process. In most instances, it is unreasonable to expect regulators to have the expertise in all facets of multi-criteria decision making related to this relatively new agrifood industry. This complexity is compounded by the recent, rapid growth of aquaculture that has affected additional stakeholders in addition to the owner /operators themselves. These are individuals or groups that also need to be part of the decision making process (ICES 2003). These issues have, in part, been justification for the increased use of more formal decision support systems for aquaculture management and development.

A number of decision support systems have been proposed, or are presently used by the aquaculture industry for a variety of purposes. The specific objectives of each decision support system may vary, focusing on areas such as; facility design/management (Ernst, Bolte and Nath 2000), site selection (Stagnitti and Austin 1998, Hargrave 2002) or evaluation of environmental impact potential (Silvert 1994, Brister and Kapuscinski 2002). A decision support system that encompasses all aspects of sustainability for all types of operations would be extremely large, overly complex itself, and potentially unwieldy. However, the nature of a particular operation will by default, partition relevant sustainability criteria. Any logical approach then taken in decision analysis, must address overall sustainability issues at a conceptual level first, in order to identify relevant criteria and the overall value of the proposed project. This can be followed by the selection of a more detailed and appropriate decision support system which will embody applicable expertise related to, say, environmental siting criteria for example, within the larger framework of sustainability.

Development of a Decision Support Tool for Freshwater Cage-Aquaculture Licensing

This formal, decision matrix approach is being proposed for the licensing of finfish cage aquaculture in Ontario, Canada. A decision support tool (DST) has been developed by us, and is presently being tested and reviewed in conjunction with Provincial, Federal, industry and other community stakeholders. The licensing of cage-based aquaculture in Ontario is complex and dynamic, especially in the Great Lakes where the majority of the province's food fish production occurs. This is due largely to overlapping jurisdictions and interests of federal Departments (e.g. Fisheries and Oceans, Transport Canada, Environment Canada), provincial ministries (e.g. Natural Resources, Environment, Northern Affairs and Mines, and the Ministry of Agriculture, Food and Rural Affairs), and a variety of other industry, First Nations and non-governmental organizations

(NGOs). As a result, licence applications are required to pass through several agencies for approval; a painstakingly long and laborious procedure. To address this issue, the lead aquaculture licensing agency, the Ontario Ministry of Natural Resources, initiated the development of a Harmonized Guidelines approach, intended as a 'one stop' application procedure to streamline and improve the licensing process. The DST presented here is consequently embodied as part of the new Harmonized Guidelines and they are intended to be used together.

Within this design framework, the DST developed here was developed to accommodate the following objectives:

- Display decision criteria and their ranking in each section, so users can understand how compliance decisions and rating criteria are determined.
- Clearly demonstrate how data provided by the applicant is used. This ensures that agencies requesting the data provide rationale as to how and why the information is required.
- DST data inputs and criteria that could trigger a licence refusal are requested early in the application process. This is intended to avoid unnecessary costs associated with 'late discovery' of some basic information that otherwise would have resulted in obvious licence refusal (i.e. the proposed location is not compliant with Navigable Waters Protection Act) had it been provided at the onset of the application process.
- Each section (e.g. water quality, operations) is accompanied by a support document produced by a multi-agency writing team, which assesses the state of knowledge of their respective section, and recommends rating or decision criteria based on existing compliance and research findings.
- Individual sections and the overall licence rating criteria will return a red (licence refused), amber (cautionary) or green (section approved) rating; a similar conceptual rating approach proposed by Hargrave (2002).
- Constants and compliance values assessed by mathematical formulae are stored separately so these values can be easy updated as the science improves or compliance values change.
- Develop the DST in a commonly used and easily understood software platform. Given the relatively small size of the industry in Ontario, and the small number of people who would be using the DST, and allowing for the potential for continual updates, we felt that the DST would be most practically developed in an Excel ® (Microsoft Corp.) based, spreadsheet application. In this way, computer programmers are not required; sections or cells can be password protected if required (to prevent tampering); and the general familiarity and availability of this spreadsheet software in most organizations reduces the need to train staff on new application software.

The DST developed here, effectively 'rates' such areas as water quality, operations, ecosystem impacts (such as species at risk and fish, communities/ habitat/ health), user conflict, physical site aspects, sediment impacts etc., and provides a variety of functions to assist in overall application assessment. These sections require a series of questions to be answered or have data entered depending on the licence stream ('New Licence' or 'Re-issue'), or type of water body proposed for the farm (e.g. either 'closed' or 'open' site locations). Specific details, organizational requirements, structure and various decision criteria that we employed are detailed in Table 1. Interface examples from the spreadsheet application are shown in Figure 1.

Discussion and Conclusions

Existing legislative requirements for Ontario aquaculture often result in very specific, 'go' or 'no go' criteria, negating the need to proceed with more complex decision support systems. However, once the obvious 'no go criteria' have been addressed in an application, a decision support system will be a very useful tool for the assessment of more subjective criteria for which there may be less clearly defined compliance criteria. One of the challenges with the development of the Ontario DST occurred when writing teams were presented with the task of addressing the subjective criteria in their discipline area, and defend how they should be rated. Most teams returned specific trigger limits or, ‘no’ or ‘go’ decisions for the licence, resulting in relatively few subjective responses that led to a ***cautionary*** rating. In some cases, compliance values were already in existence, although in other cases, the absence of scientific support data appeared to discourage attempts to justify a range of ‘appropriateness’ within subjective ratings.

Dealing with subjectivity of analysis can be a potential strength or weakness of any given decision support system. Where there is an absence of scientific justification for a particular decision outcome, or where legitimate differences in the value-based judgements of various stakeholders exist, a default to a somewhat ‘arbitrary’ threshold may occur, and inevitable – and controversial- debate will arise. For example, some stakeholders may see an adverse impact where others see a benefit in the exact same parameter! How then, should such criteria be ranked? Differences in opinion are unavoidable, and their resolution will no doubt be situation and site specific. However, formal decision support systems can help to quickly identify those specific issues where stakeholders may disagree, and do it early in the decision-making process. This will ultimately assist in the negotiation processes that are often required to reconcile these differences, and lead to a more expedient decision outcome.

Future developments in world aquaculture systems, such as open ocean technologies (Marra 2005) and integrated, multi-trophic systems (Troell et al, 2002, 2004; Neori et al. 2004) are intended to improve aquaculture sustainability through either reductions in stakeholder conflicts, mitigation of ecosystem effects, or in combinations of both. Such developments will introduce ever-greater complexity into aquaculture decision making, and will create an increased demand for the development of decision support tools like the one described here.

As the aquaculture industry evolves, it is important to appreciate that a decision support system that facilitates sustainability is not an end unto itself, and the ‘support’ aspect of the tool needs to be emphasized. Decision support systems do not, and should not, exclusively make the decision to establish a new farm, or expand an existing farm operation. Rather, they should foster accountability and efficiency of the process employed to assess farm applications and arrive at decision outcomes. For example, if decisions are made in contradiction to a DST recommendation, the regulators and other decision makers should be required to provide a legitimate and defensible justification for this apparently conflicting decision outcome.

Ultimately, a valid decision support system will ensure that the appropriate criteria for environmental, social and economic sustainability criteria have been considered, while accommodating a transparent rating system that is available to, and accepted by, all stakeholders.

Table 1. Section Descriptions and Organization of the DST.

Info Sections in DST	Description
DST Contents and Site map	
Project Description	Describes project goals and rationale
Application Schematic	Analogous to a site map
Administration	Applicant information, dates, names of reviewers etc.
Licence type	Type will dictate application stream and activate appropriate questions for the stream
Proposed production	Displays proposed production output and links to ‘Production and husbandry section’
Escape risk and security	Reports results from ‘Risk analysis and security’ section
Site location	Reports site location details entered in the ‘Operations’ section
Operations	
Operational Layout	Reports operational layout
Stage 1 application process	Initial application and review details
Stage 2 application process	Applicable legislation, process requirements, site markings, consultations and stage 3 requirements
Stage 3 application process	Data collection, draft application submission, continued consultation, concern mitigation
Stage 4 application process	Submission of final application, decision making and notification
Site Details	
Site location	Latitude, longitude and regional location (e.g. water body)
Production and husbandry	Proposed species and annual production targets
Infrastructure	Cage type, moorings, layout, depth, distance from shore, site dimensions, support structures
Standard operating protocol (SOP)	Is there an SOP for Environmental monitoring, escape prevention/reporting, Fish Health Management Strategy, Feed Management Strategies
Site Decommissioning	Determines if an acceptable site closure plan has been submitted
Physical Parameters	
Lake type classification (Decision stream)	Lake type is entered here (I, II, or III). The type will dictate question and data requirement steams for the DST
Flushing and currents	Approximates flushing rate of site based on mean current velocitie
Bottom contour map	Imports maps. Used to asses sediment footprint

Info Sections in DST	Description
Water Quality	
Total phosphorus	Entry and assessment of total phosphorus data. Determines if median concentrations are below regulatory guidelines
Dissolved oxygen	Entry and assessment of dissolved oxygen data. Determines if concentrations and percent saturation are below regulatory guidelines
Sediment Effects	
Organic matter	Entry and assessment of total organic mater (TOC) data at the site boundary and reference location
Phosphorus	Entry and assessment of sediment Tot-P organic mater data at the site boundary and reference location
Nitrogen	Entry and assessment of total Kjeldhal (TKN) data at the site boundary and reference location
Ecosystem Impacts	
Risk of Escape	Returns facility requirement based on presence of species in receiving waters and rudimentary Genetic risk assignment (as per Provincial licensing requirements)
Fish habitat	Questions answered about distance of site from feral fish nurseries, spawning beds and up-welling areas
Fish communities	Status of existing of fish community assessment data in the area, ‘special value populations’ and predator stocking rate)
Fish health	Distance form other fish cage operations
Species at risk	Assess species at risk data, and if range overlap, are there mitigating measures to correct
Section consensus	Describes questions and data still required or section outcome
User Conflicts	
Navigation	Approval status under the Navigable Waters Protection Act
First Nations concerns	Aboriginal consultation, land claim issues, dispute resolution process if needed
Section consensus	Describes questions and data still required or section outcome
Numerical Constants	
Sediment Severe Effects Levels	Total phosphorus (%), total organic carbon (mg/g) , total Kjeldahl Nitrogen (mg/g)
Water Quality Compliance	Total phosphorus (µg/l), dissolved oxygen (mg/l), % oxygen saturation

Info Sections in DST	Description
Nutrition and Waste	% phosphorus digestion, % feed waste, % non-settleable solids, % phosphorus retention in carcass and mean fecal settling rate
Selected conversions	Conversion values listed for some common units
t-test formula	Details t-test formulae used to assess significant difference between reference site (e.g. sediment)
Farm Maps and Diagrams	Essentially a storage area for e-versions of maps required as part of the application process
Map of site location	Stores imported map
Map of 'Site footprint'	Stores imported map
Functions and Supporting Information	Information and functions to assist usage for DST
Analytical Quantification Calculator	Details relationships between, lower level of detection, instrument detection level, method detection limit and limit of quantification
Classification of Genetic Risk	Genetic risk assessment calculator. An initial rudimentary assessment of risk on proposed culture species (based on existing Provincial classifications)
Lake Type Assessment	Details characteristics of lake type determination (lake type will affect the application stream and consequently data requirements)
Cage and Farm Volume	Farm and cage volume calculator
Species Eligible for Culture	A list of species legal for culture in the province
Acts and Regulations	Hyperlinks to applicable legal Acts and Regulations
Class EA categories	Details environmental assessment classes that could be invoked for major works
Phosphorus modelling	Estimates potential change in localized or water body phosphorus concentrations
Theoretical footprint	Rudimentary depositional model from single point source
User Instructions	Provides operating instructions for user
Final DST Recommendation	
Data Assessment	Displays the section rating criteria of Operations, Physical, Water quality, Ecosystems and User Conflict
Overall Rating Criterion	Reports final outcome of licence assessment

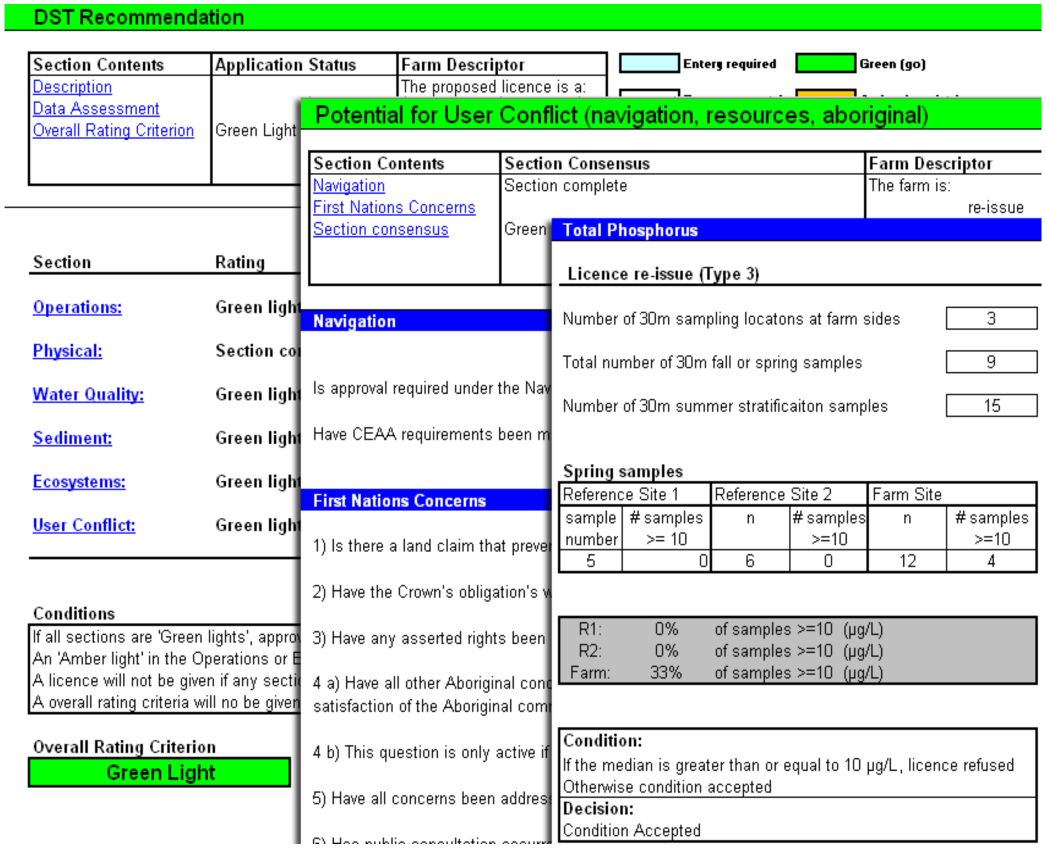

Figure 1. Selected DST Interface Examples

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