Models for the assessment of sustainability and risk in fish and shellfish aquaculture

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FISH AND SHELLFISH FARMING OBJECTIVES

LONGLINE ENVIRONMENT CONTEXT & EXPERIENCE

Longline Environment was incorporated in 2005, to provide marine environmental products and services based on 20 years of research and technology development experience. The company offers a range of consultancy services from aquaculture to water quality issues for aquaculture farms, stakeholders, insurance companies & brokers, environmental agencies, etc.

The team has carried out projects all over the world and worked with many of the major institutes (PML, UOS, IFREMER, NOAA, EPA, SOA). Longline's team track record include projects carried out in the United States, China, The Republic of Ireland, Scotland, Northern Ireland, Portugal, France, Italy, South Africa and Mozambique. Projects have been executed in ecological modelling, sustainable carrying capacity, fisheries management and eutrophication management.

FISH FARMING: CREATING A SUSTAINABLE INDUSTRY

Stakeholders have a trade-off between short-term profitability and long-term sustainability. The implementation of best management practices (BMP's) can aid fish farmers to achieve profitability and facilitate the provision of aquaculture insurance. Aquaculture growers must determine resource requirements and the price of those resource requirements. Considerations such as land costs, yield/seed costs, staff costs, feed costs and disease control costs all influence the return on an investment.

The variable costs faced by a farmer vary (e.g. according to geographical location) and will affect the profitability of a farm. These costs include the cost of seed, feed, legal permits, etc. The stocking cost depends on both the seed price and stocking density. The price of seed is dependent on juvenile age, as older juveniles have a higher survival rate.

ACCESS MARKETS

The level of profitability of a fish/shellfish farm will depend on the ability of farmers to sell their product. The ability to target export markets is essential and is related to factors such as the quality of product, production costs, competition, transport issues and accessibility to distributors. Farms with a high level of concern for environmental factors, best management practices and traceability can achieve certification, increasing their chances of reaching export markets.

CARRYING CAPACITY FOR AQUACULTURE

Assessments of sustainable aquaculture are conditioned by different definitions of carrying capacity, which may be regarded as physical, production, ecological and social. These are themselves modulated by scaling, usually considered to be either system scale (bay, estuary or sub-units thereof), or local scale (farm).

To overexploit an area will have severe effects on the commercial productivity and potentially also on ecosystem health. A method to predict the ability of coastal environments to sustain aquaculture is required for successful development of the industry through the determination of the carrying capacity.

The concept of carrying capacity of an ecosystem for natural populations is derived from the logistic growth curve in population ecology, and defined as the maximum standing stock that can be supported by a given ecosystem for a given time. Carrying capacity estimates in terms of aquaculture (production) may be defined as the stocking density at which production levels are maximized without having a negative impact on growth. Carrying capacity for aquaculture can be further defined as the standing stock at which the annual production of the marketable cohort is maximized.

It is important to assess the carrying capacity of an area prior to the establishment of large-scale finfish and shellfish cultivation, to ensure an adequate food supply for the anticipated production and to avoid or minimise any ecological impacts.

Carrying capacity assessment is in the interest of stakeholders, regulators/environmental agencies and aquaculture insurers to analyse the sustainability of aquaculture operations.

FACTORS OF CONCERN

Objective	Issues	Factors
Production	Growth	Overstocking
		Feeding
	Mortality	Dissolved oxygen
		Disease
Profit	Costs	Seed
		Optimisation
Markets	Product quality	Seed
		Feed optimisation
Plant & Equipment	Physical damage	Storm, Floods

AQUACULTURE INSURANCE

Our primary focus with respect to aquaculture consultancy for insurance purposes lies in production analysis for finfish/shellfish/prawn farms, and potential risk factors associated with water quality and local environmental issues. These factors present, an added value for underwriters and insurance brokers as a tool to help identify risks with respect to aquaculture insurance proposals.

Some of the areas that may be of interest include:

- To help evaluate the risk of a particular proposal, on the basis of (i) regional context and (ii) farm-scale context.
- To help with post-facto evaluation of claims etc, to establish the bona fides of the problem which clients are claiming for.
- The development of bespoke insurance products for oysters, mussels, clams, scallops, shrimp and tilapia.

For the aquaculture insurance industry we divide our analysis between the valuation of aqua farms and the valuation of risk.

Issue	Approach
Valuation of aqua farm	Production analysis of aqua farms using mathematical models, assisting the insurance industry to profile insurance candidates.
Valuation of risk	Assessment of insurance risks based on calculation of: • Eutrophication potential based on feeding, stocking densities and physics (climate, water renewal, etc) • Prediction of dissolved oxygen • Mortality risks • Harmful Algal Blooms (HAB)

AQUACULTURE MODELLING FOR INSURANCE

The types of models developed by Longline Environment Ltd. focus on the production, and combine physical processes, cultivation practice and biogeochemical processes. These models can be used individually or simultaneously to analyse production, water quality, animal mortality, eutrophication issues, effluent quality/ risks, etc.

Some of our modelling tools for fish/shellfish operations include:

- EcoWin2000
- FARM (Farm Aquaculture Resource Management)
- ASSETS (Assessment of Estuarine Trophic Status)
- Geographic Information Systems (GIS)

EcoWin2000

EcoWin2000 is an ecological model for aquatic systems. It resolves hydrodynamic and biogeochemistry issues and can incorporate population dynamics for target species (such as shellfish). The model uses a range of equations depending the application requirements, and may be used as a research model to examine aquaculture development scenarios and nutrient loading. It has been extensively tested in international research projects and is potentially a useful tool for supporting an ecosystem approach to sustainable aquaculture development.

For aquaculture insurance purposes EcoWin2000 can be used to analyse the growing potential of aqua farms in a particular bay or region, e.g. Chesapeake Bay in the United States. Despite EcoWin2000 being able to address insurance concerns, it has historically been more suited to the needs of water managers and environmental agencies than the insurance sector due to large data requirements, and the fact that it deals with the scale of a whole bay or estuary.

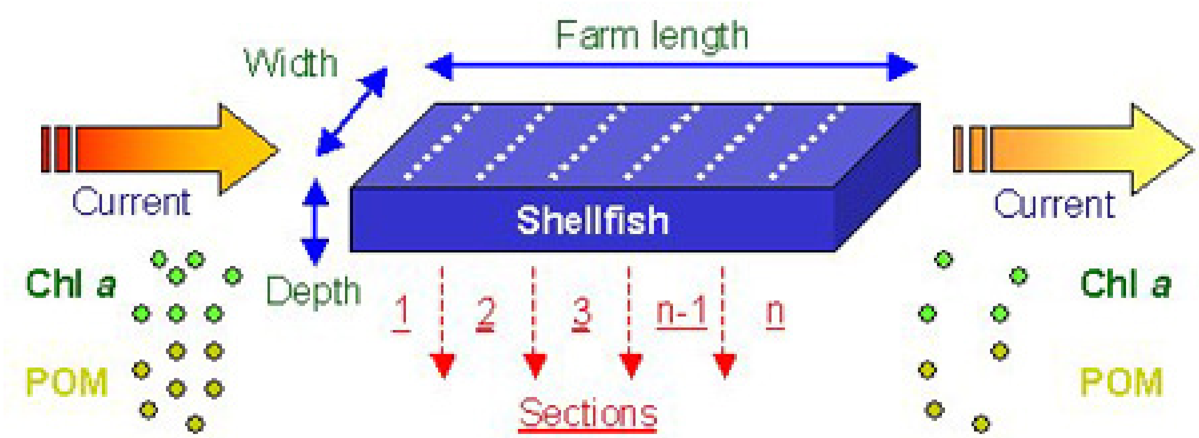
For actuarial purposes, models that function in a smaller spatial domain, such as the FARM™ (Farm Aquaculture Resource Management) model, yield more relevant results when analysing fish/shellfish aquaculture.

FARM™ (Farm Aquaculture Resource Management)

FARM™ can assist an underwriter or insurance broker in assessing whether a particular shellfish site is suitable for production according to the farm dimensions, location, and other data required in aquaculture insurance proposal forms. In addition, it may be possible identify sites using a combination of FARM™ and the Assessment of Estuarine Trophic Status (ASSETS) model, that are likely to suffer from eutrophication and nuisance/toxic algal blooms, helping underwriters to improve risk selection for insurance.

The FARM™ model is a tool for assessment of coastal and offshore shellfish aquaculture at the farm-scale level and address four primary issues:

- Prospective analyses of culture location and species selection;
- Ecological and economic optimisation of culture practice, such as timing and sizes for seeding and harvesting, densities and spatial distributions;
- Environmental assessment of farm-related eutrophication effects;
- Determination of the value of ecosystem goods and services with respect to the reduction of eutrophication, as a substitute of land-based nutrient removal.



The modelling framework applies a combination of physical and biogeochemical models, bivalve growth models and screening models for determining shellfish production over a specific time period and for eutrophication assessment. In addition, shellfish species combination (i.e. polyculture) may also be modelled.

To experience the look and feel of FARM™ please visit our Winshell site at http://www.longline.co.uk.

ASSETS

The Assessment of Estuarine Trophic Status (ASSETS) model can be used to determine whether proposed insurance risks, based on their location are susceptible to suffer from eutrophication and Harmful Algal Blooms (HAB) which could potentially result in the mortality of animals in an aqua farm.

ASSETS allows aquaculture insurance providers to choose better risks with respect to eutrophication and toxic algal blooms.

The Assessment of Estuarine Trophic Status (ASSETS) evaluates influencing factors, eutrophic condition and future outlook, combining them into a single overall rating called ASSETS. Each of the component ratings is determined using a matrix approach. The ASSETS synthesis combines the Infuencing Factors (IF), Eutrophic Conditions (EC) and Future Outlook (FO) ratings into a single score falling into one of five categories that are colour coded: “High”, “Good”, “Moderate”, “Poor”, or “Bad”.

• Influencing factors (IF) is a combination of a system’s natural susceptibility and nutrient loading to a particular system.

• Eutrophic condition (EC) is a combined assessment of five symptoms based on:

- occurrence;
- spatial coverage;
- frequency of problem occurrences.

Ratings are determined from a combination of the average scores for chlorophyll and macroalgae, primary symptoms indicating the start of eutrophication and the worst score of the three more serious secondary symptoms, which include low levels of:

- dissolved oxygen;
- submerged aquatic vegetation;
- nuisance/toxic algal blooms.

• Future outlook (FO) predicts what future eutrophic conditions will likely be by combining susceptibility and expected changes in nutrient loads (including management measures) to determine future conditions.

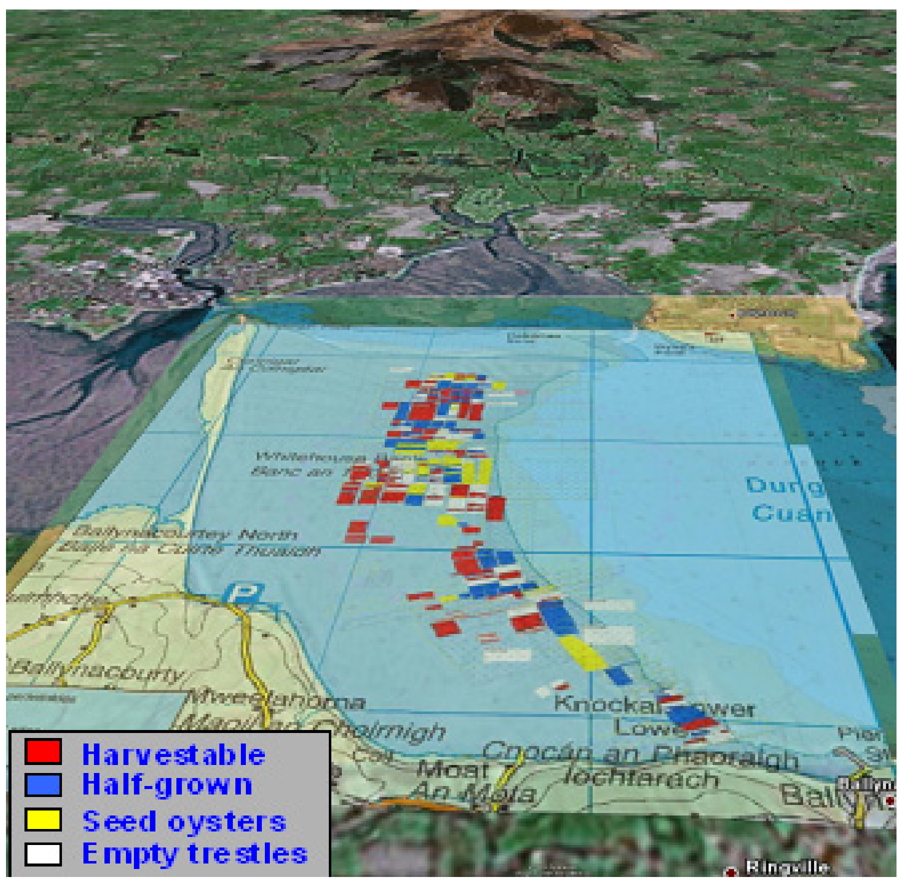
GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Geographic Information Systems ("GIS") provide the ability to store, view, visualise and analyse spatial data. Bathymetrical and morphological features can be integrated into GIS projects, together with spatial information on shellfish aquaculture areas, distribution of wild species, water and sediment quality.

The use of spatial data is valuable for integrated modelling projects, such as:

- Definition of spatial domains, i.e. model boxes.
- Spatial visualisation of water quality data, by loading the GIS project with appropriate databases.
- Data extraction using common GIS functions (reclassifications of grid cells, geostatistical analysis, map algebra for:
    - Area and volume calculations;
    - Assessment of benthic biodiversity;
    - Distribution of aquaculture features.

On the right: an application of GIS illustrating oyster leases in an Irish bay. The seed oysters are moved to the half-grown areas after roughly one year of growth, these in turn being transplanted to the harvestable areas in the final year of cultivation.



Another example of GIS application is a particulate waste distribution model that may be developed for spatial analysis using GIS, to provide a footprint of organic enrichment beneath fish farms. A representation of fish growth is used, the main emphasis being on the simulation of the trajectory of the wasted food and metabolic products. This allows for the determination of organic enrichment below the fish cages.

TECHNICAL MARKETS

The types of models developed and/or applied by Longline Environment focus on the production, and combine cultivation practice, physical and biogeochemical processes such as shellfish growth and eutrophication.

These models allow a focus on the marketable cohort of a cultivated population, and provide outputs such as production and average physical product (APP). Because growth is simulated based on the food supply, which determines the distribution of individuals into different weight classes, we are able to calculate the food loss, and simulate its effect both on water quality, through oxygen depletion and excessive algal growth, and on the profitability of the business, provided basic financial data are made available.

FURTHER INFORMATION

Due of the specificity of each site, a generic evaluation is challenging, and probably unsuited to the complexity of the problems at hand. Longline does not focus on the disease component, which is presently impossible to simulate for predictive purposes, but can contribute to assessment and valuation of risk with respect to other factors of production, such as growth rates and mortality due to low oxygen derived from eutrophication and other factors.

We can also assist in determining whether water quality standards in emission waters will be appropriate, thereby addressing other business risks such as non-compliance fines from regulatory authorities.

KEY CONTACT

For further information please contact:

Rui Gomes Ferreira
2nd Floor, 145-157 St John Street
London, EC1V 4PY
United Kingdom
Email: info@longline.co.uk