LENKA—a Method for a Nation-wide Analysis of the Suitability of the Norwegian Coast for Aquaculture

H. KRYVI*, H. O. IBREKK† and S. ELVESTAD*
*LENKA Secretariat, Ministry of the Environment, P.O. Box 8013 Dep., N-0030, Oslo 1, Norway
†Norwegian Institute of Water Research, P.O. Box 69 Korsvoll, N-0808 Oslo 8, Norway

The last ten years the aquaculture industry in Norway has boomed. The rapid expansion has caused different kinds of environmental and managerial problems that need to be adressed. A coastal zone management programme called LENKA was started in 1987. The aim is to make an efficient and standardized tool for coastal zone planning. Consideration is taken to the environment, existing utilization and infrastructure aspects connected to the Norwegian coastal waters. A model for estimating the production capacity for aquaculture is set forth. The model deals with conditions connected to the recipient and to the surface area. The coast is divided into three categories of recipients based on topography. Each category is given a production indice, quantifying the aquaculture production possible without harming the environment. The recipient capacity is compared to the different constraints put on the surface area, and a figure for net capacity is given. The method has been used at county level.The results are summarized to give a national overview of the potential for aquaculture industry in Norway.

The prospects for utilizing the Norwegian coast, consisting of islands and fjords for aquaculture are promising. So is the growth of the aquaculture industry in Norway as shown in Fig. 1. In 1989 the production of salmon and trout was 118,000 tons.The rapid expanding aquaculture industry adds to the pressure on the inherently sensitive and often already stressed environments bringing increased and intensifying competition for coastal space. The rapid expansion of the aquaculture industry has caused pollution problems and conflicts with traditionally fisheries, transport at sea, open air recreation life, nature conservation and naval defence. In addition there are problems with diseases, spreading of infections, use of antibiotics and environmental threat in the form of possible genetic depletion caused by mixing of wild and escaped farmed salmons.

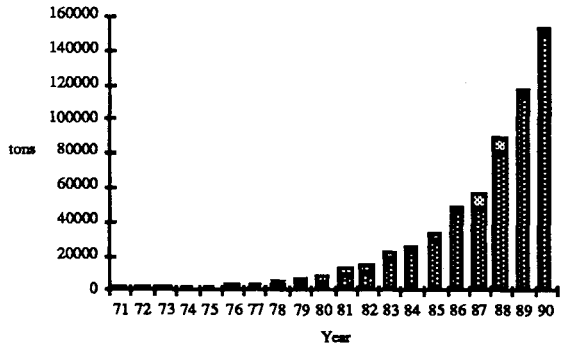

Fig. 1 Salmon and trout production, 1971-1989, and prognoses for 1990 (Source: Fish farmers sales organization).

The organisations involved in licensing of approving aquaculture ventures are under pressure lacking resources regarding the tackling of problems caused by the rapid growth. Most problems can be avoided by reasonable siting of the farms, but no comprehensive plans for siting have existed. The LENKA-project is meant to provide tools for such planning at the county and municipal level, and establish a flexible database thus contributing to a balanced and orderly development of the aquaculture industry in Norway.

Organization

The LENKA-project is a cooperative project between the Ministry of Fisheries, the Ministry of Local Government and the Ministry of the Environment. The project is run by a professional secretariat (LENKA-secretariat). The LENKA-secretariat together with three expert groups have been responsible for the development of the working methods (Marine Environment, Water courses and Maps and Computing). The project was initiated in 1987, and was terminated summer 1990. The budgett for the project period has been US$ 5.5 million.

Marine Pollution Bulletin, Vol. 23, pp. 785–788, 1991.
Printed in Great Britain
0025-326X/91 $3.00+0.00

The working procedure

The main working procedure(LENKA documents,1989) is shown in Fig. 2. In order to deal with our 57,000 km long coastline in portions of manageable size the coastal areas are divided into smaller, appropriate geographical units, such as archipelagos, a fjord, a large sound, or an open fjord basin. These major water volumes, called the LENKA-zones, are handled separately.The typification process (2) and the capacity assessment process (9) will be explained.

Typification of zones is a registration of the environmental properties of the area, and is based on four main groups of parameters: environmental conditions, existing use of the zone, existing infrastucture and special areas within the zone. Under heading of each of these parameters, data are collected and systemized. The compiled information for each zone is transferred to maps. Environmental factors that are mapped: pollution, sea temperature, ice cover, exposure (wave height), depth conditions, basins and salinity. Existing use: settlement, recreation (boating, bathing etc), port development, fisheries, shipping traffic, other factors. Infrastructure: road development and electricity, distribution of processed fish, processing facilities, health- and guiding service, offal disposal systems. Special areas: nature reserves, spawning grounds, existing fish farms, protection zones for salmon.

Model for capacity assessment. A procedure for estimating the gross available capacity for aquaculture production in LENKA zones, has been developed. This enables authorities to set up production figures for each zone. A flow diagram of our procedure is shown in Fig. 3.

Classification of coastal areas. Each LENKA zone is divided into smaller areas based on assumed water exchange rate derived from knowledge of topography. We have defined three recipient categories:

A: Open coastal areas and large fjords (>10 km, no sills) where depth is larger than 50 m.

B: Open areas and fjords where only one of the following conditions is met: length< 10 km, depth<50 m, presence of sills.

C: Small silled fjords and enclosed areas (length<10 km and presence of sills).

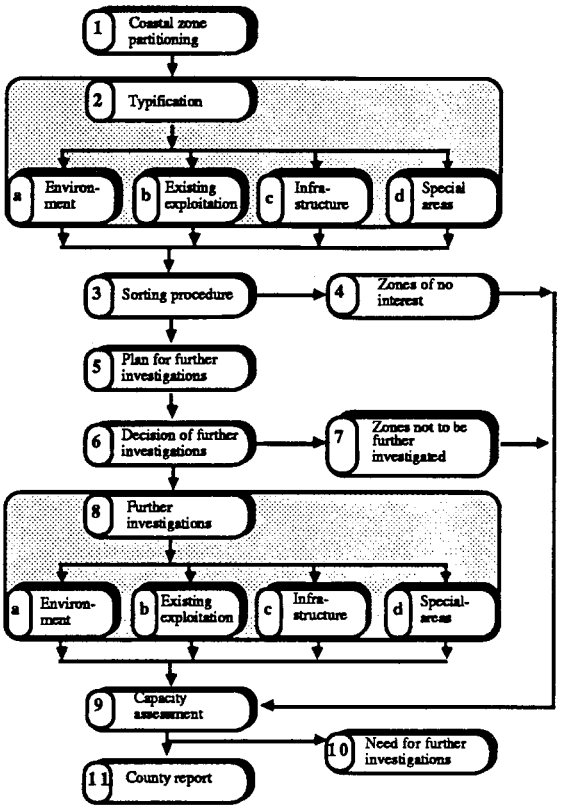

Fig. 2 The main working procedure for the LENKA-project.

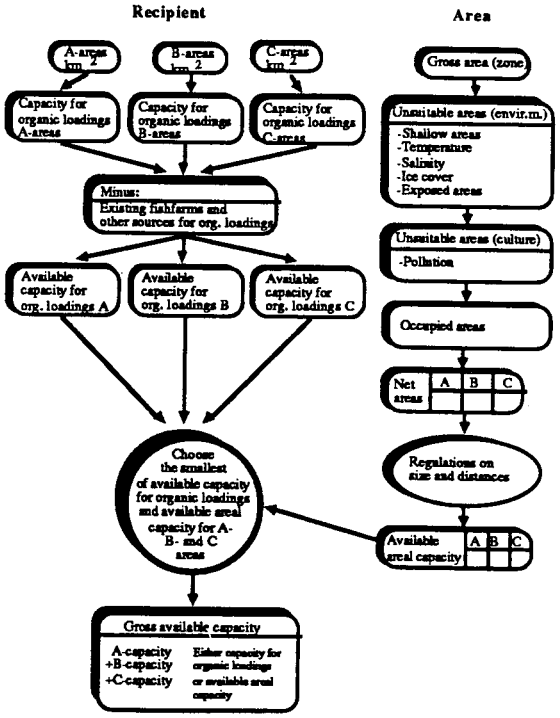

Fig. 3 Protocol for calculating the gross available capacity for LENKA zones.

Model for capacity assessments

The model for capacity assessment is divided into two parts. Evaluation of the conditions:
- in the watervolume, the recipient, and on the surface area.

The recipient capacity.

Setting up production figures includes two major concerns :
- organic loadings from the aquaculture production shall not promote any degrading of the environment
- healthy conditions for the fish within the cages shall be sustained

Due to lack of definite environmental quality standards and suitable theoretical models, an empirical approach was chosen. About 150 independent investigations on the effect of fish farm pollution at different types of sites in different parts in Norway have been screened. A thorough evaluation of production figures, feeding routines, topography data and the environmental response (hydrography and bentos), has been undertaken and correlated to the actual type of water exchange regime (A-, B- or C- area). Based upon this sample, linking the production figures to the environmental impact, indices for production in each category has been proposed. (The following figures for organic loading per year from an average fish farm (mean production of about 300 tons per year), has been used: 3 tons of total phosphorous, 27 tons of total nitrogen and 150 tons of BOD_7.)

The indices are: (numbers in tons produced fish per km^2):

	A	B	C
Southern part of Norway	60	30	15
Northern part of Norway	90	60	30

Because of greater tide differences the values of the indices given in the northern regions are larger.
These figures are inaccurate and give merely a rough estimate for production in larger areas, the LENKA zones. They will also indicate the need for further investigations, and the calculations are tied up to a close surveying programme including hydrographic and bentos investigations.

Multiplying these indices with the size of each categorized area, gives the overall capacity of organic loading. From this loading potential, contributions of organic matter from other sources as industry, agriculture, sewage, existing fish farms and natural run-off are subtracted. For every categorized area relevant data are collected and special models for processing the data are used. Total nitrogen has been chosen as an indicator parameter for organic loading, primarily because this parameter is considered to be the growth limiting factor in the coastal waters of Norway.

The Area capacity.

Parts of the categorized areas are unsuitable for cage culture, as it is put into practise in Norway today. Environmentally unfavorable factors as: exposure to rough sea, low sea temperatures, ice cover, low or unstable salinity levels, shallow areas and pollution are considered. The size of the suitable areas are calculated and multiplied with an empirical indice called area indice (150 tons per km^2, an average fish farm produces 300 tons per year and occupies about 2 km^2).

The result, called available area capacity, are compared with the available capacity for organic loading for that particular categorized area. The net results gives the gross available capacity.
A dataprogramme handling the database and the calculations is developed.

Final assessment of the production capacity.

The suitability of each area is further evaluated as to the extent of possible conflicts between aquaculture industry and other interests. These interests are: spawning and fishing grounds,

open air recreation activities, nature reserve, naval defence, shipping traffic, protection zones for salmons and so forth (see typification chart).
In addition infrastructure in the area is considered: road development, processing facilities, offal disposal systems, health service and guiding services.
Evaluations of other interests and infrastructure are done on a qualitative scale. The results are linked to the calculations of the gross available capacity mentioned above.

The LENKA-method thus provides the planners and politicians with a rough estimate of the amount of aquaculture production that can be achieved in a certain area without risking degradation of the environment and ensuring healthy conditions for the caged animals.
In addition the method forward a procedure that aims to eleminate conflicts between fish farming and other interests . Together with an analysis of infrasture it is possible to do an overall consideration of the area as to its suitability for aquaculture activities.

Results

- Siting of fish farms should mainly take place in A- and B-areas.
- The annual production of farmed fish can potentially increase with 570,000 tons/yr without causing detrimental environmental effects and user conflicts.
- The potential of 570,000 tons/yr is basically located in A-areas (90%).
- Approximately 70 per cent of the potential can be found in the nothern counties.
- Most of this potential can be developed without establishing new infrastructure.
- Of the potential of 570,000 tons/yr, 120,000 tons/yr are found in zones with user conflicts. Coastal zone planning is required in these zones.
- The LENKA prosject shows that 9 per cent of the Norwegian coastline is suitable for locating fish farms. Of the suitable areas 5 per cent can be found in A-areas, 45 per cent in B-areas and 40 per cent in C-areas.
- 80 per cent of the Norwegian coastline is susceptible to exposure (maximum 2 m wave height)
- 85 per cent of the coastline does not meet the environmental criteria
- 15 per cent of the coastline can not be used for siting of fish farms due to existing exploitation.
- The area capacity for the Norwegian coast is equivalent to a production of 900,00 tons/yr and the recipient capacity equals a production of 4 million tons/yr. The area capacity is thus the limiting factor for development of the aquaculture industry of the two.

Closing remarks

The LENKA-method can be used by the central authorities analyzing the consequences of changing political settings for aquaculture. The local authorities are given a planning tool for coastal zone planning in general and for aquaculture planning in particular.
The method is however inaccurate when it comes to assessing production figures for smaller areas and predictions of sites for the individual farms. Further, some of the basic information units are not digitalized, which makes it cumbersome to operate. The process of improving the method has now started.
Our simple approach for calculating capacity for organic loading is tentative and will be replaced by a mathematical model (Aure et al.,1990). This model gives the oxygen concentration at certain depths taking water exchange, topography, latitude, organic loading from land sources into account. The model will give a more precise estimate of the amount of organic waste from fish farms that can be tolerated without harming the environment. Together with a monitoring programme including bentos investigations this model will comprise a reliable tool for site evaluations and capacity calculations.
To make the model operational the categorized areas, A-,B and C-, will be digitalized. By doing this, exchange of different information tied to this topographic unit, will be eased.

LENKA documents(1989). 9 reports. A short description in English.
Aure,J. & Stigebrandt,A. (1990). Quantitative estimates of eutrophication effects on fjords of fish farming.Submitted for publication in *Aquaculture.*