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LENKA - A NATION-WIDE ANALYSIS OF THE SUITABILITY OF THE NORWEGIAN COAST AND WATERCOURSES FOR AQUACULTURE. A COASTAL ZONE MANAGEMENT PROGRAM

by

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ABSTRACT

A coastal zone management program called LENKA was started in 1987 and is to be terminated in 1989. The aim is to make an efficient and standardized tool for coastal zone planning, which, pertaining to law, is the responsibility of the county and municipality. The program aims to be beneficial for both the environment and for the fish farmers. Consideration is taken to all important existing utilization and judicial aspects connected to the Norwegian coastal waters. This is done by a systematic collection of all available data, systemized in such a way that they are available for future planning.

A model for the evaluation of the holding capacity primarily for cage culture based on both oceanographical and topographical criteria is put forth. The coast is divided into three categories of recipient based on topography. A central clue in this model is the evaluation of indices for the quantity of aquacultural activities (measured as organic deposits into the recipient) one may have per square kilometer in differently categorized recipients.

INTRODUCTION

Aquaculture in Norway is based on salmon and rainbow trout. The growth of the industry has been rapid, with an almost two fold production increase every second year. The total production this year is expected to be about 80 000 metric tonnes, but the continued growth is expected to be slower. Up to now, the limitation has mainly been on the number of smolts available, this situation is now reversed, partly due to the liberation of smolt production permits.

There is a keen interest in the potential of cultivating marine species, especially halibut and cod. Much effort is put into solving the problems of the rearing of juveniles, and this seems to be solved for cod and turbot. Other species of interest are arctic char, wolf fish, eel and lump fish. Some shellfish are being cultured, mostly blue mussels and oysters, in addition to experiments on scallops. Also and some experiments on ranching of lobster is being performed.

The main asset in Norway for this rapid growth in the aquaculture industry has been the access to vast amounts of water of good quality, both fresh water and salt water. Space and water quality was not a limiting factor to begin with, but is becoming so now. So far, the only measurement available in the assessment of holding capacity, is the amounts of organic waste from mariculture.

There is a need for a planning tool, consisting of directions and knowledge, to aid the development in such a way so that a high productivity is maintained at the same time as conflicts with fisheries, conservation interests, leisure activities and other utilization is kept low. The tool will have to be standardized and rational.

Both county and local municipality have the need for a plan on how to utilize the marine resources. The county plan is a guiding one, the judicial binding is not persistent before there exists a plan approved of by the local municipality.

This paper, written by the expert group on marine environment, presents the biological and oceanographical aspects of the project.

This is a description of an ongoing project where the guidelines are not yet completed. As we believe that there is a considerable interest in these matters, we find it appropriate to give some information on the project at its present state.

THE PROJECT

The project is a cooperation of three ministries, the Ministry of Fisheries, the Ministry of Environment and the Ministry of Local Government and Labour. Its name **LENKA** is a Norwegian abbreviation meaning: A Nation-wide Analysis of the Suitability of the Norwegian Coast and Watercourses for Aquaculture.

The project aims to :

* To contribute to a continued positive development and growth of the aquaculture industry with minimal conflicts with other utilizational and conservational interests.

* To contribute to the county and municipality planning in the coastal areas and watercourses.

* To contribute to the siting process of aquacultural activities.

The project is a planning tool, and not a plan in itself. Further, it does not aim at the site as a working level, but handles larger areas as the base unit, later referred to as LENKA zones.

Project organization :

Figure 1 gives a schematic picture of the project organization.

The development of the working methods is done by the three expert groups and the secretariat at the Ministry of Environment, while the gathering of data, map work etc, is to be performed by the county project organizations. The three expert groups are placed at the institutions with the relevant competence. The group working with watercourses

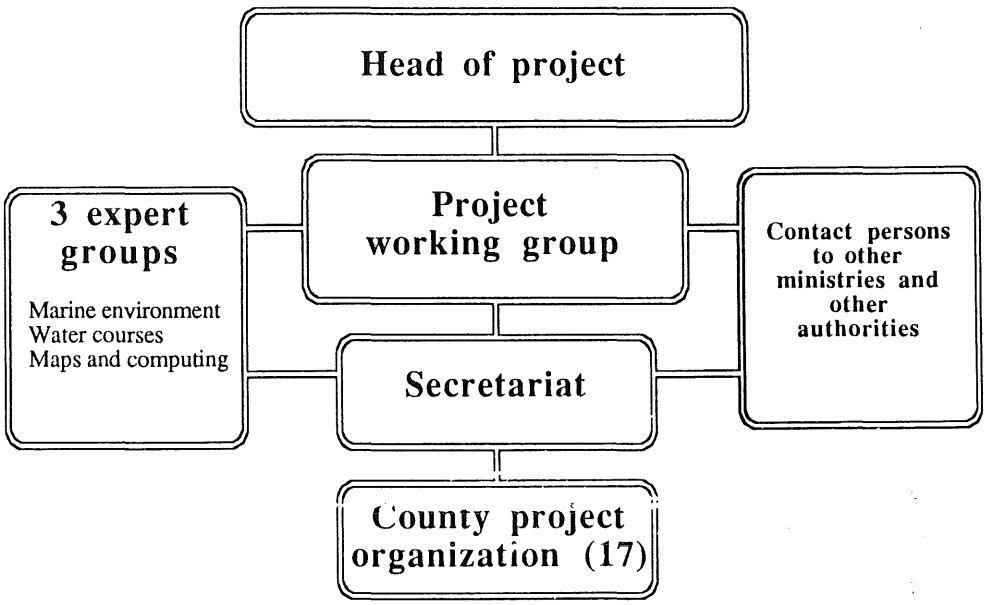

Figure 1: The LENKA - project organization. The head of the project consists of the Secretaries General from the Ministries of Fisheries and Environment. The project Working group has 3 members from the Ministry of Fisheries, 3 from the Ministry of Environment and 1 member from the Ministry of Local Government and Labour. The Secretariat is placed at the Ministry of Environment.

is placed at the Directorate for Nature Management, Trondheim. The group working with maps and computing is placed at the Norwegian Hydrographic Service, Stavanger. The two latter's part of the project will not be presented in this paper.

The group working with the aspects concerning the marine environment is placed at the Institute of Marine Research, Bergen. In addition, the group also has members from other institutions, such as the County Environmental Protection Department, the Ministry of Environment and Nordland College, Bodø.

The project has a total cost of 40 million NOK spread over three years.

THE MAIN WORKING PROCEDURE

The main working procedure of the project is shown in figure 2 (next page).

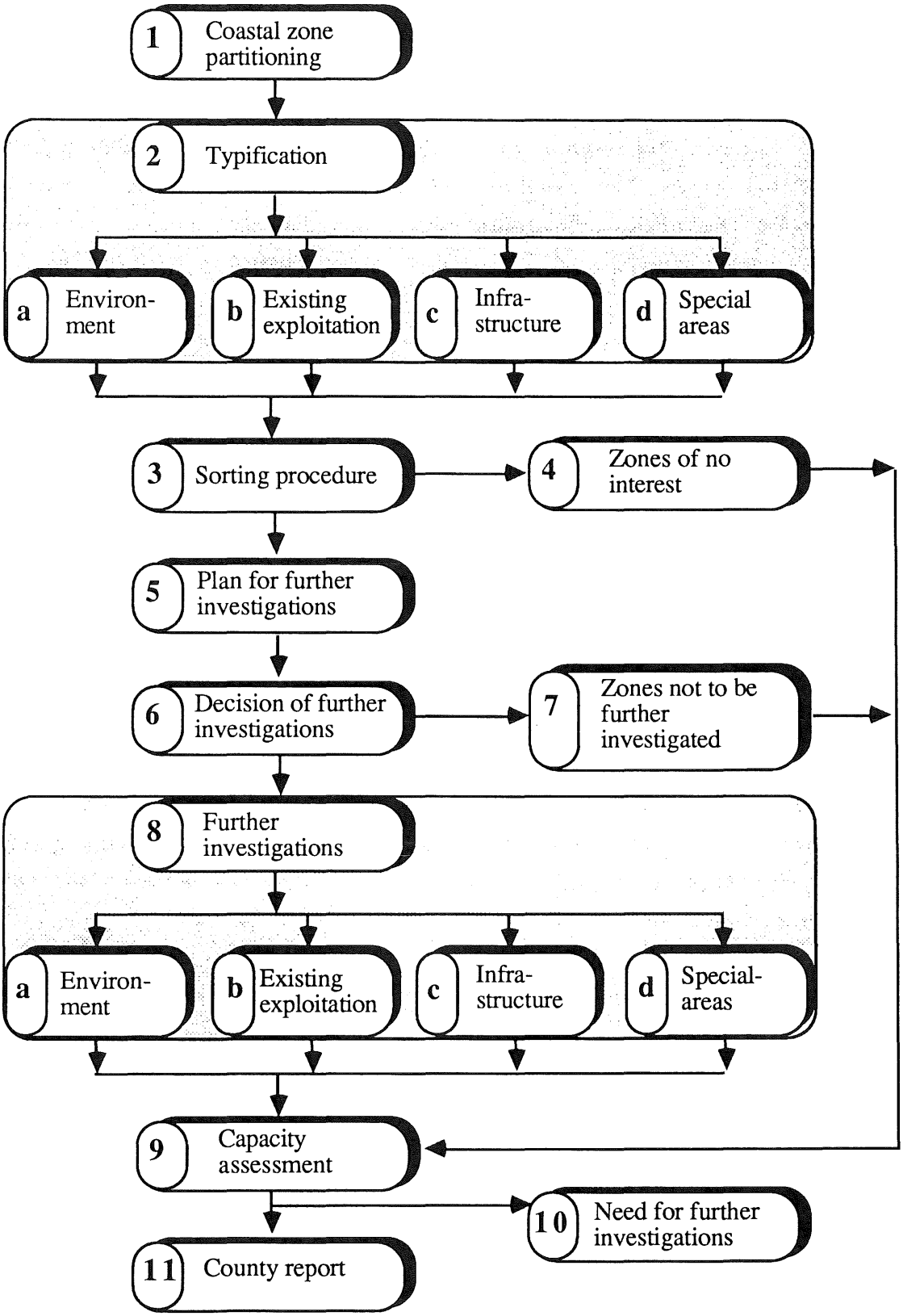

Figure 2 : The main working procedure of the LENKA - project.

ZONE PARTITIONING

In order to be able to deal with our 57 000 km long coast line in portions of manageable size, a partitioning is necessary. The principle of the partitioning is that each major water volume should be handled separately. Roughly, the coastal zone is divided into smaller areas (LENKA-zones) each being either an archipelago, a fjord, a large sound or an open fjord basin. The smaller areas will reflect the water bodies capacity to handle the organic loadings received from both aquaculture and other sources.

In order to separate the water volumes, the borders should to a large extent as possible follow land. An example of how this looks like is shown in appendix 1, where the partitioning of County Hordaland (where Bergen is situated) is shown.

TYPIFICATION

Typification of zones is a registration of the environmental properties of the area. In this project the aim is to collect and systemize the data that already exist. For some parameters the data will be scarce. This is taken into consideration, and follows the description of the area. The compiled information will be transferred to maps, the result being a visualized presentation of the environmental properties of the marine environment. Similarly, this is done for the other three main groups of parameters, Existing exploitation, Infrastructure and Special areas.

The following parameters and their significance were used for the typification of the zones. These are the major environmental parameters that have influence on the utilization of the coastal areas for aquaculture. We would like to note that we do not consider any technological devise that frees the farming installment from the marine environment surrounding it. This is mere a question of economy, and will not be considered in this project.

ENVIRONMENTAL PARAMETERS USED FOR TYPIFICATION OF ZONES :

Pollution :

The point in this connection is that the contamination of the environment effects the health or the marketability of the fish raised in these waters. Also, we distinguish between two categories of pollution; toxins as one kind and organic loadings as another. Most important are the massive outlets from industry and agriculture. Some areas are severely polluted by heavy metals and toxins from specialized industries. In addition there are several smaller sources of various kinds of pollution with a more or less restricted effect on the marine environment.

Temperature :

When considering temperature conditions in Norwegian waters, low temperatures is the main hindrance of aquacultural activities, though there are some problems with too high summer temperatures in some parts of the country. Of interest are the extreme temperatures occurring within a time span of 5 - 6 years (our definition of frequent). Areas reckoned as unsuitable for aquaculture have regular long periods, that is 6 weeks or more, with temperatures below zero centigrade. Measurements ought to be taken at depths of 2 to 5 metres.

Ice cover :

Of interest are the areas covered with ice at least every five years.

Exposure :

The actual parameter here is wave height, though current velocity also is part of the exposure problem. Current in itself only occurs as a problem locally, but infers on the wave height. Suitable areas for cage culture is where the wave height does not exceed 2 m. For wind to generate such a wave height, a stretch of 10 km open water is needed. Here we would like to add that the general development of the aquaculture industry in Norway has been towards more robust cage constructions, with cage systems being able to stand up to wave heights of up to both two and three metres.

Depth conditions :

The depth required under the cages is dependent on the current velocity to ensure that the wastes from the farm is spread. Also this is a way to

avoid possible eruptions of hydrogen sulfide gas from the sediment that often accumulates under the cages to reach the fish in the cages. As a general rule we have set 20 m depth to be a minimum criterion for cage culture, with the possibility of adjustments to current velocity.

Basins :

A basin is a water volume restricted from the outer lying larger water masses by a threshold. A basin is defined as where the depth of the basin is at least 10 m deeper than the threshold. This water volume is sensitive to organic loadings, causing a possible disturbance of the oxygen balance. All thresholds shallower than 50 m have been registered.

Salinity :

The influence of freshwater causes several problems for the fish farms. A layer of brackish water on top of the salt water resulting in a strict stratification, may cause severe fluctuations in salinity and also fluctuations in temperature. As a limit for when the influence of fresh water becomes a problem, we have put the salinity measurement to 25 ppt.

Other main groups of parameters :

Under the heading of existing exploitation we list the followings parameters :

- effects on settlement patterns
- open air recreation life
- port development
- fisheries
- shipping traffic
- other factors .

Further, there is a separate heading called infrastructure, dealing with the particular requirements which should be met for an aquaculture enterprise to succeed. Main parameters are :

- road development
- distribution of manufactured feed
- processing facilities
- health service and guiding service
- offal disposal systems.

The last heading is special areas, conditions that might conflict with

further development of aquacultural activities. Examples here are :

- spawning grounds for important fisheries species
- reserves for coastal birds and marine mammals
- others.

A MODEL FOR CAPACITY ASSESSMENT

Some imperative reservations :

With capacity we mean holding capacity, which is : the maximum production limited by a non trophic resource. Or put in a simpler way, what quantity of aquacultural activity is possible in an area without there being damage caused to the environment. This is measured as deterioration due to organic overloading causing eutrophication, oxygen depletion a.s.o..

This method of capacity assessment of LENKA zones is based on the emphasis of two main considerations :

1) the environmental impact from mariculture
2) the marine environment's impact on the cultured organism.

It is by no means possible to give exact values on what loadings from mariculture are acceptable, that is, how much organic waste from mariculture is possible without any negative influence on the surrounding environment. Some general recommendations are given in the State Pollution Control Act, the entire aspects are being dealt with by the Ministry of Environment and the State Pollution Control Authority. The total environmental impact from fish farms will manifest themselves several years after the farm has started production.

To be able to assess any capacity for aquaculture, one has to take into consideration the contribution from all major sources of organic loadings.

Elements of the capacity assessment :

Many parameters affect the capacity assessment. Not only the above mentioned parameters are of importance. The LENKA - project takes into consideration the elements shown in **figure 3**, and the working procedure is shown in **figure 4**. As is shown, there are two main aspect in the

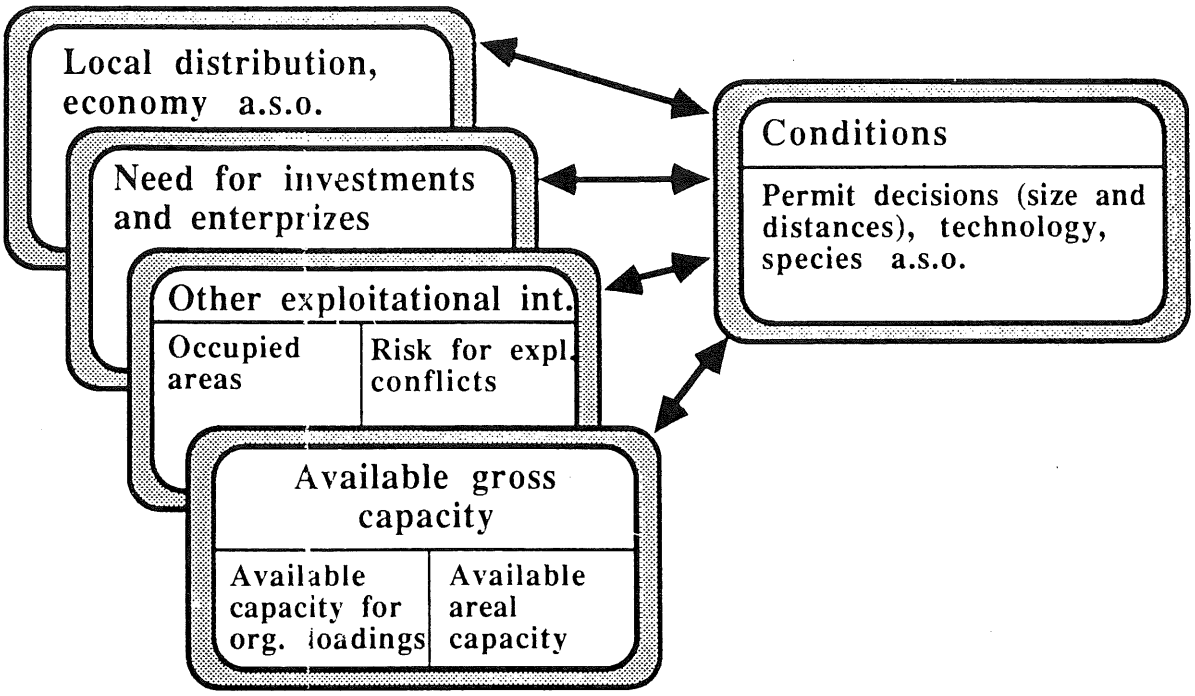

Figure 3 : Elements of the capacity assessment.

capacity assessment. One aspect is the evaluation of the capacity for organic loadings in water body (LENKA zone). This is done by treating the zones properties as a recipient for organic loadings. The other aspect is based on space. The water body, or more precise, parts of it, is occupied by other activities as mentioned earlier. There exists a net area available to aquacultural activities. One of these will set the limit to aquacultural activities.

In our capacity assessment we have based the calculations on organic loadings, and thereby neglected limitations set by factors such as risk for spreading of diseases, use of chemicals and therapeutica etc. There exists a veterinary regulation on distance between farms, this is set to 1 km. Criteria as such may be altered as the knowledge increases.

The recipient capacity :

Classification of coastal areas within the zones :

Classification is based on topography. This again reflects the water exchange regime in the area, as well as being an indicator of the area's

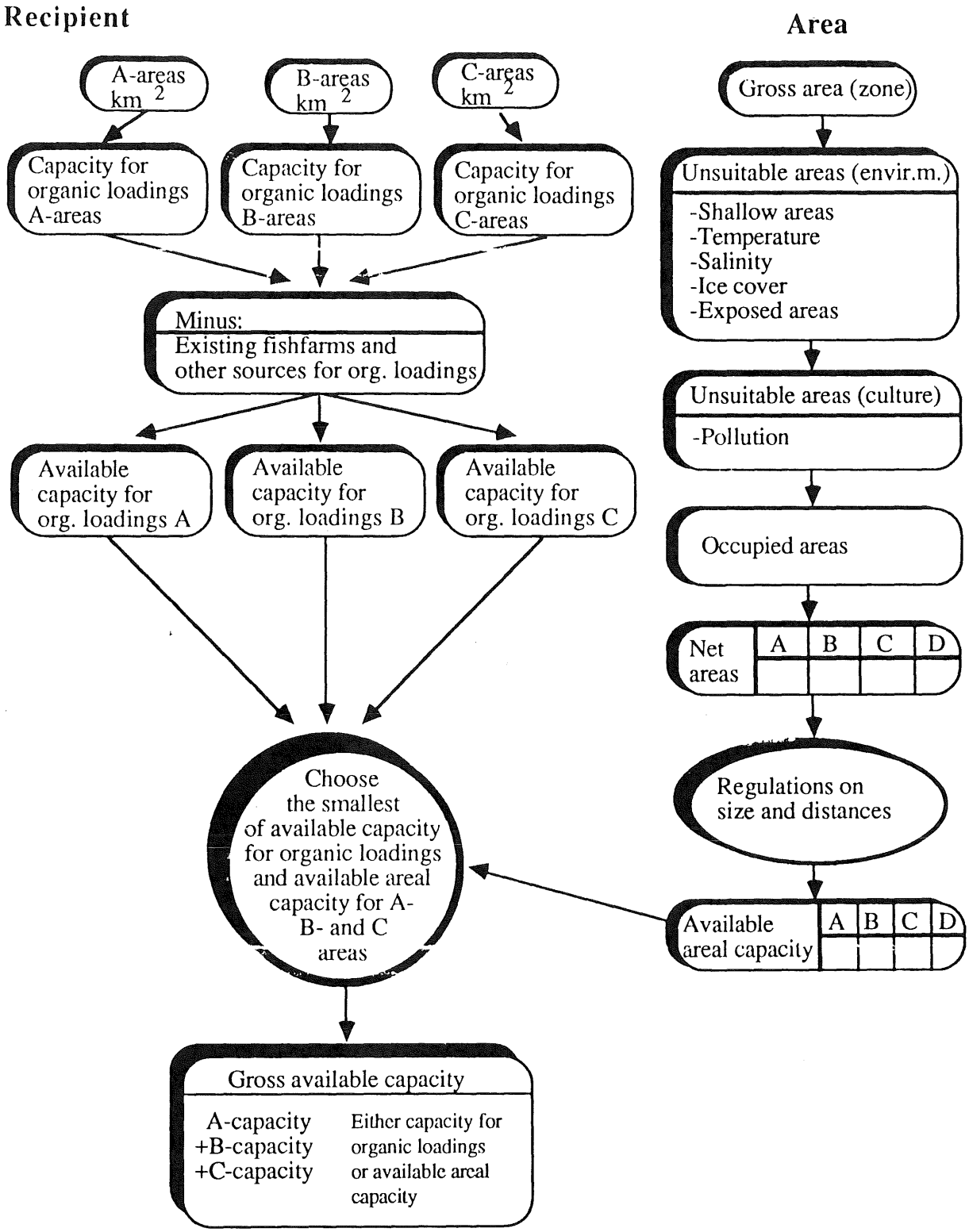

Figure 4 : Calculation of gross available capacity.

property as a recipient. An exact classification with illustrations is given in Appendix 2.

For each recipient category A, B and C there is given an index for how much aquacultural activity is recommended. This is expressed as a certain production in terms of tonnes per square kilometre. Here we would like to emphasize what care was taken before these indices were given. The procedure was as follows :

From empirical data we were able to extract the general statement on how large production one could have in a specific area without it causing damage to the environment. The effects were investigated by sediment fauna monitoring. These levels of production were converted to production per square kilometre. Again, based on facts about Norwegian fish farms, these values were converted to organic loadings, expressed as oxygen consumption, total phosphorous and total nitrogen.

As a correction factor one would have to adjust these figures for other major outlets of organic waste. At the moment we are, together with the appropriate institutions, giving a simplified method for estimating the impact on the marine recipient based on key figures ready available. The capacity is calculated in terms of organic waste, and is therefore independent on the technology being used. New technologies resulting in reduced outlets from the farms can easily be incorporated in the calculations.

Further, when capacity is expressed as production as tonnes per km^2, this sets restriction to the size of single farms and to the total activity in larger areas. The values are not decided yet, but the capacity will be expressed as the following :

A - categorized areas : a maximum production per (4x4) km^2, but not more than a lesser specifies quantity at a single site. A site is defined as occupying a minimum of 1 km^2. Where the recipient conditions are particularly good, and the number of sites available is restricted, one may exceed these recommendations.

B - categorized areas : similarly as above, there is given a maximum production per (4x4) km^2, and a lesser one at a single site.

The capacity per (4x4) km² will be in the magnitude within one thousand metric tonnes for both A- and B - categorized areas.

C - categorized areas : these areas are basins and silled fjords, and special care should be taken in such areas. Aure & Stigebrandt have developed a model for the calculation of oxygen consumption in silled fjords (Aure and Stigebrandt 1988, Stigebrandt and Aure 1988), and this can in turn be used as a method for the calculation of capacity in terms of organic loadings. The calculations can be done given the hydrographic data and topographical maps.

Where there is oxygen depletion in the basin water, aquacultural activities are not recommended in silled fjords. In basins within archipelagos one should ensure that the water in the deeper layers of the basin does not suffer from oxygen depletion. This means that in an area categorized as a C grade recipient, no aquacultural activities are recommended before one has sufficient data so that damage to the environment is avoided.

This method is dependent on a monitoring and control scheme, and this will have to be a perpetual process. In this way there is the possibility of adjusting the proposed capacity assessment, and at there is possibility of keeping an eye on what is happening to the environment. The monitoring and control schemes are not established.

The areal capacity

Unsuitable areas :

Each LENKA - zone has a gross area divided into A, B and C type recipients. Parts of these areas may be unsuitable for aquaculture, that is, unsuitable for cage culture for as it is practiced in Norway. Unsuitable areas consist of environmentally unfavorable areas from both natural conditions and as a result of man's activities. The last case is mainly pollution, and in this case pollution of toxicants that directly affect the fish health and marketability.

The environmental parameters taken into account are : Shallow areas, cold water, low salinity, ice cover and exposed areas.

In addition to these unsuitable areas there are certain areas that are

bound up by other activities. Such areas are :

- area already occupied by existing aquacultural activities
- nature reserves and animal protection areas (both birds and sea mammals)
- security zones for salmonid fish

In addition areas are occupied for military purposes and for ship navigation.

Having subtracted all these areas, one is left with a net areal capacity which can be compared with the recipient capacity. The smallest of these will set the limit. All these calculations will be performed by computers as all the information is to be tabulated ready for a for this purpose constructed work sheet.

Finally, we would like to mention the work initiated to eliminate the interactions between wild stocks of salmon and trout and farmed fish. The possibility of affecting the genetics and spreading of diseases has been much debated. There is now suggested temporary protection zones for salmonids, with a supporting research program. Further information on this is available on request.

In addition to the names and addresses in the author list, there are a few more names to add. If anybody should have any particular interests, the following persons may be contacted :

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Appendix 1 :

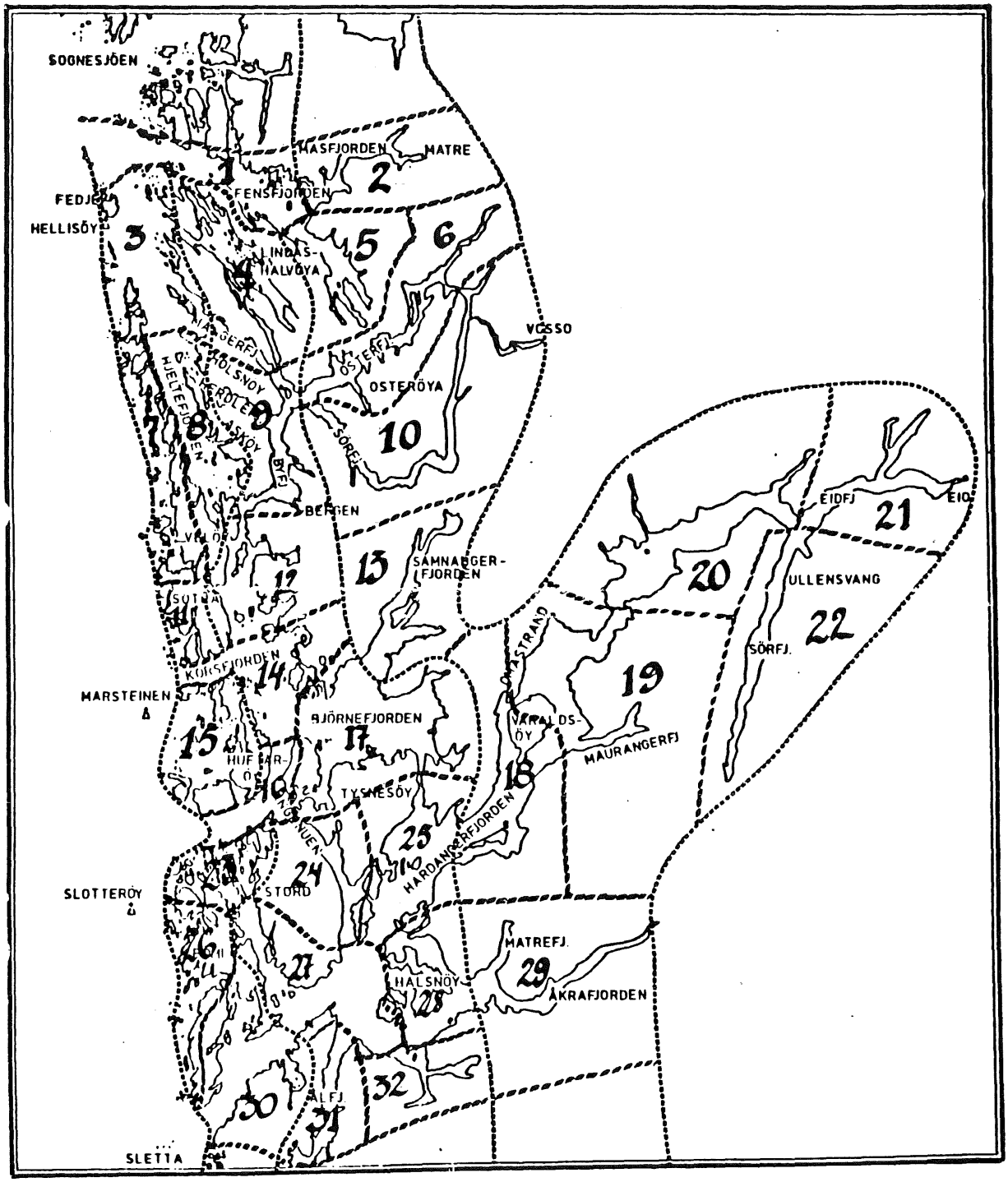

Figure 5 : Example of zone partitioning for the County Hordaland, Western Norway.

Appendix 2 :

Division of the coastal zone into smaller areas based on assumed water exchange rate caused by topography.

A : Open coastal areas and large fjords where depth is larger than 50 m.

A_1 : Open coastal areas where depth is larger than 50 m. Size and sills are not considered.

A_2 : Large fjords where :
Length of more than 10 km, and
No presence of sills[1].

B : Other areas with good water exchange.

B_1 : Open, sill - free areas as A_1 (archipelagos) and large fjords as A_2 but where largest depth is less than 50 m.
Length above or less than 10 km.
Depth[2] is less than 50 m.
No presence of sills.

B_2 : Smaller fjords, bays and inlets where :
Length is less than 10 km.
No presence of sills.
Depth is greater than 50 m.

B_3 : Large, silled fjords[3] where :
Length is greater than 10 km.
Presence of sills.
Depth may be more than 50 m.

C : Small silled fjords an other silled areas (archipelagos) :
Length of fjord less than 10 km.
Presence of sills[4].
Depth may be more than 50 m.

Examples are shown on the sketch on the next page.

[1] : A silled area is defined as an area where the inside basin is at least 10 m deeper than the sill. Sills down to 50 m are registered.

[2] : Fjords are reckoned as shallower than 50 m when more than 60 % of the area fulfills this criterion.

[3] : Fjords and other areas with several succeeding sills is reckoned as a "new fjord" when the succeeding sill is shallower than the preceding one.

[4] : In sounds and basins within archipelagos with several sills, the deepest sill is reckoned as the main entrance to the basin.

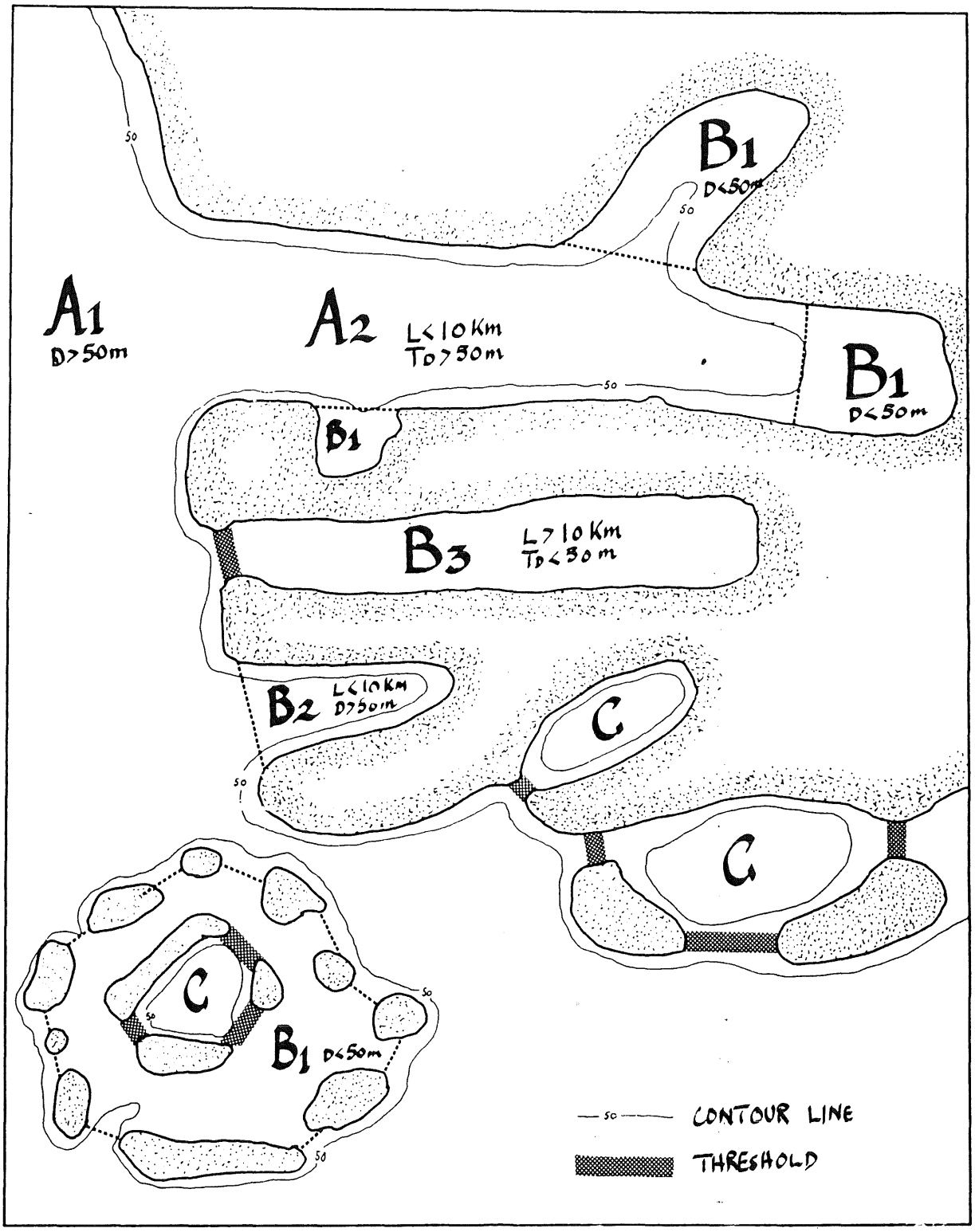

Figure 6 : Examples of division into categories A, B and C.

Legend : D = depth, L = length, T_D = threshold depth.