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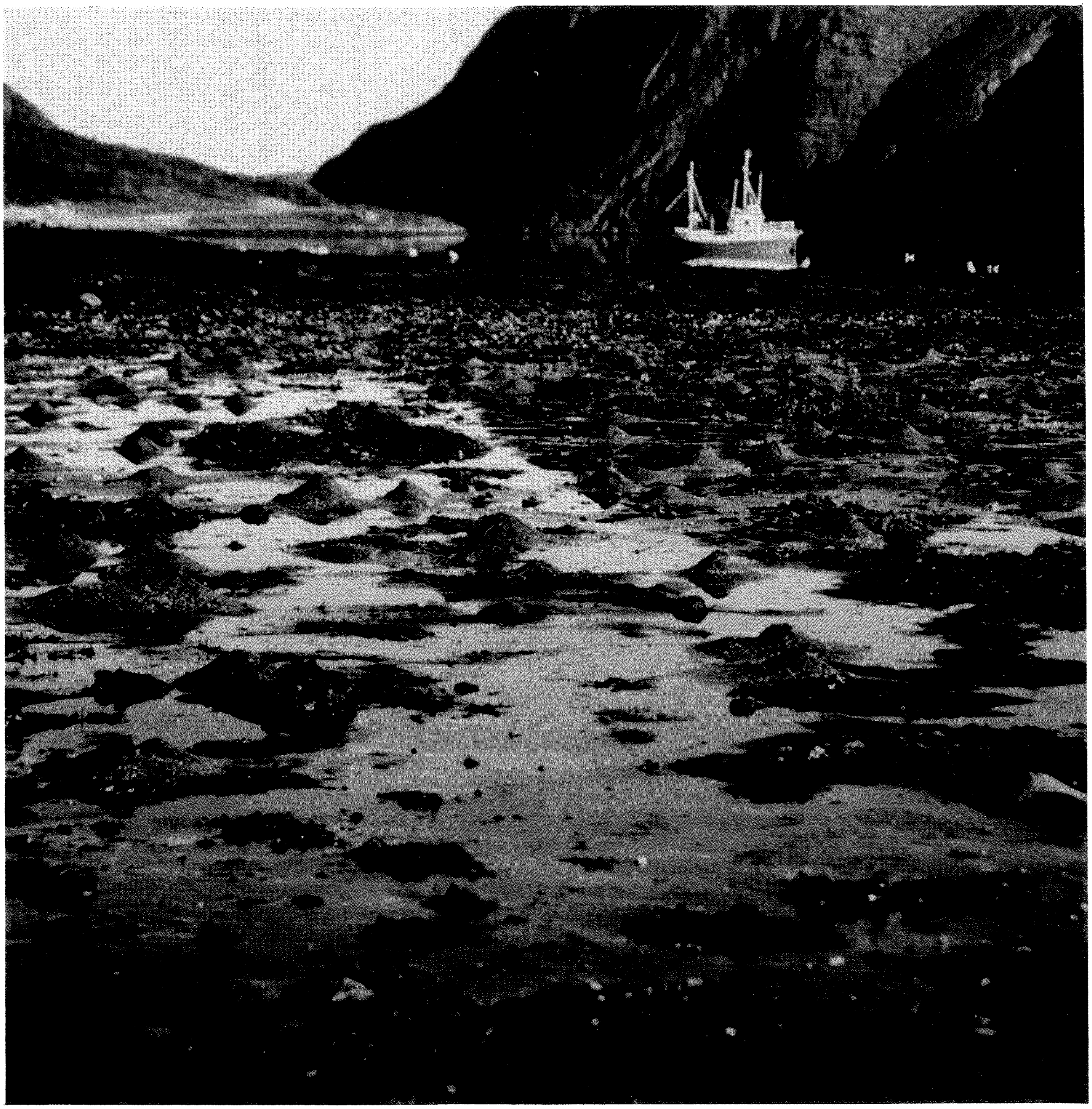
Environmental Impact Assessment for the Heidrun Field Development



Norwegian Institute for Water Research NIVA

NIVA - REPORT

Norwegian Institute for Water Research NIVA

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Abstract: The report reviews the potential sources of impact from the oil and gas exploration and production in the Heidrun field, and the current environmental status in the areas predicted to be influenced by an oil spill or other activities related to the field development. An assessment of the potential impact on offshore and coastal ecosystems and populations, fishery resources, aquaculture and other human activities on the coast is made.

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1. Heidrun-feltet	1. The Heidrun field
2. Miljøvirkninger	2. Environmental impact
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Project leader

For the Administration

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PREFACE

The present document gives an assessment of the potential environmental impact of the development at the Heidrun oil and gas field at Haltenbanken Block 6507/7. The report has been prepared by Norwegian Institute for Water Research (NIVA) for client CONOCO NORWAY INC. (CNI) on Contract Agreement no PTS-039 dated June 17 1987. The project work commenced at June 3 1987 and the first draft of the final report was finished by September 1 1987.

The work has been performed by NIVA and by research institutions subcontracted by NIVA. The following persons and institutions have been responsible for preparation of the various chapters of the report:

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Shore type and sediment characteristics	K. Næs, NIVA
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The subcontracting institutions have delivered separate interim reports. The interim reports on oil spill modelling and seabird populations have been incorporated in the main report unchanged as Chapters 4 and 5.6 respectively. The interim report on marine mammals has been divided into one chapter on offshore mammals (Chapter 3.7), and one on coastal bound mammals (Chapter 5.7). The editing of Chapters 3.7 and 5.7 has been made by NIVA, with subsequent review by Øritsland, UiO. The responsibility for any misinterpretations of the original report lies at NIVA.

In addition to the contributors listed above, we acknowledge the contibution from several of our colleges and coworkers at NIVA in performing the project and preparing the report, especially: P. Jacobsen, and I. Haugen (aquaculture), E. Børset (nature reserves and human usage), I. Svensson and L. Tveiten (editing assistance and typing), and W. Knudsen (graphics work). We also acknowledge the valuable criticism on the draft report from J. Appelbee, CONOCO.

T. Bakke and J.A. Berge have been responsible for project coordination and final editing of the report. T. Bakke has been the formal project administrator.

Oslo, October 1, 1987

Torgeir Bakke
project leader

CONTENTS

1. INTRODUCTION

The objective of the present report has been to compile an environmental impact assessment of the areas and natural resources both offshore and inshore likely to be affected by the development of the Heidrun field on Haltenbanken. Associated activities including potential environmental effects of an operation base and accidental The assessment is based on available literature and data. The information has been compiled by the various authors of the report, and critically assessed for relevance to Norwegian coastal and offshore conditions. Information concerning sources of effects from the Heidrun field development (platform types, crude oil properties, expected discharge types and rates, etc.) have been provided by CNI.

The strategy of the work has been to assess all available literature and other information for relevance to the topic, then to give a description of the ecological and other elements potentially affected by the Heidrun development. The main assessment has been to appraise the severity of a potential impact on these elements and to define the areas and seasons when such impact is considered most damaging.

2 SOURCES OF EFFECTS

2. SOURCES OF EFFECTS

2.1. INTRODUCTION

The discovery, development and production in an oil field involves processes, routines and unpredictable incidents which potentially may affect the environment. The activities are well planned and involve a calculated possibility of minor environmental effects which is acceptable when within certain limits. Some incidents are not planned and are to be regarded as accidents and may result in more extensive effects beyond the level of acceptance for planned activities. It is thus imperative to assess the potential effect of such unexpected incidents, however unlikely.

Offshore activities may potentially result in changes or modifications of the environment. An important question is however, the significance of such changes.The cause of such changes may be of physical or chemical nature and are partially a function of the crude oil properties (Table 2.1) and the quantities of oil produced.

The estimated field production data for the Heidrun field are:

Production reserve 220 000 barrels (US) per day
Production produced 200 000 barrels (US) per day
Total reserve in the field 700 000 000 barrels.
Water injection 330 000 barrels per day.

The sources of effects evaluated are based on activities, routines and incidents arising from four different scenarios possible on the Heidrun field (see Figure 2.1 for map).

2.2. SCENARIOS TO BE CONSIDERED

1. Development and production of the field according to current plans and regulations.

2. Rupture of submarine pipelines in the Heidrun field area (Heidrun to Draugen=20 nautical miles). In case of a rupture the following pressure reduction will trigger shutdown valves in order to stop the flow. The potential maximum amount of discharged oil will be equivalent to the volume in the pipeline between the two nearest

valves. At the worst this could result in a discharge of 39 000 barrels of crude oil.

3. Blowout of one well without a fire. Estimated discharge of crude oil is 20 000 barrels of crude oil per day for not more than 30 days which is the time needed to drill a relief well. Normally a blowout will be stopped within a shorter period of time by capping the well by some other method.

4. Blowout of one well which subsequently results in the whole platform taking fire. Estimated discharge of crude oil is 100 000 barrels per day. The duration of such a discharge cannot be estimated.

Table 2.1. Crude oil properties

Specific gravity 22-30 API. Average over whole reservoir 26 API corresponding to 898 kg/m^3. Methods used for determination of physical and chemical properties are indicated in brackets.

Viscosity, kinematic @ 20 C	:13.1 cSt	(IP 71)
Viscosity, kinematic @ 37.8 C	:8.79 cSt	(IP 71)
Pour Point	:-19 C	(IP 15)
Salt Content	:21 mg/l	(IP 265)
Hydrogen sulphid	:<5 ppm	(IP 103B)
Acid value	:0.31 mg KOH/g	(IP177)
Wax content	:2.60 % Wt	(Gravimetric @ -30 C)
Carbon Residue	:1.87 % Wt	(IP 13)
Ash Content	:<0.01 % Wt	(IP 4)
Vanadium content	:5.9 ppm	(Acid extraction/PES)
Nickel content	:0.9 ppm	(Acid extraction/PES)
Sodium content	:9.6 ppm	(Acid extrtaction/PES)

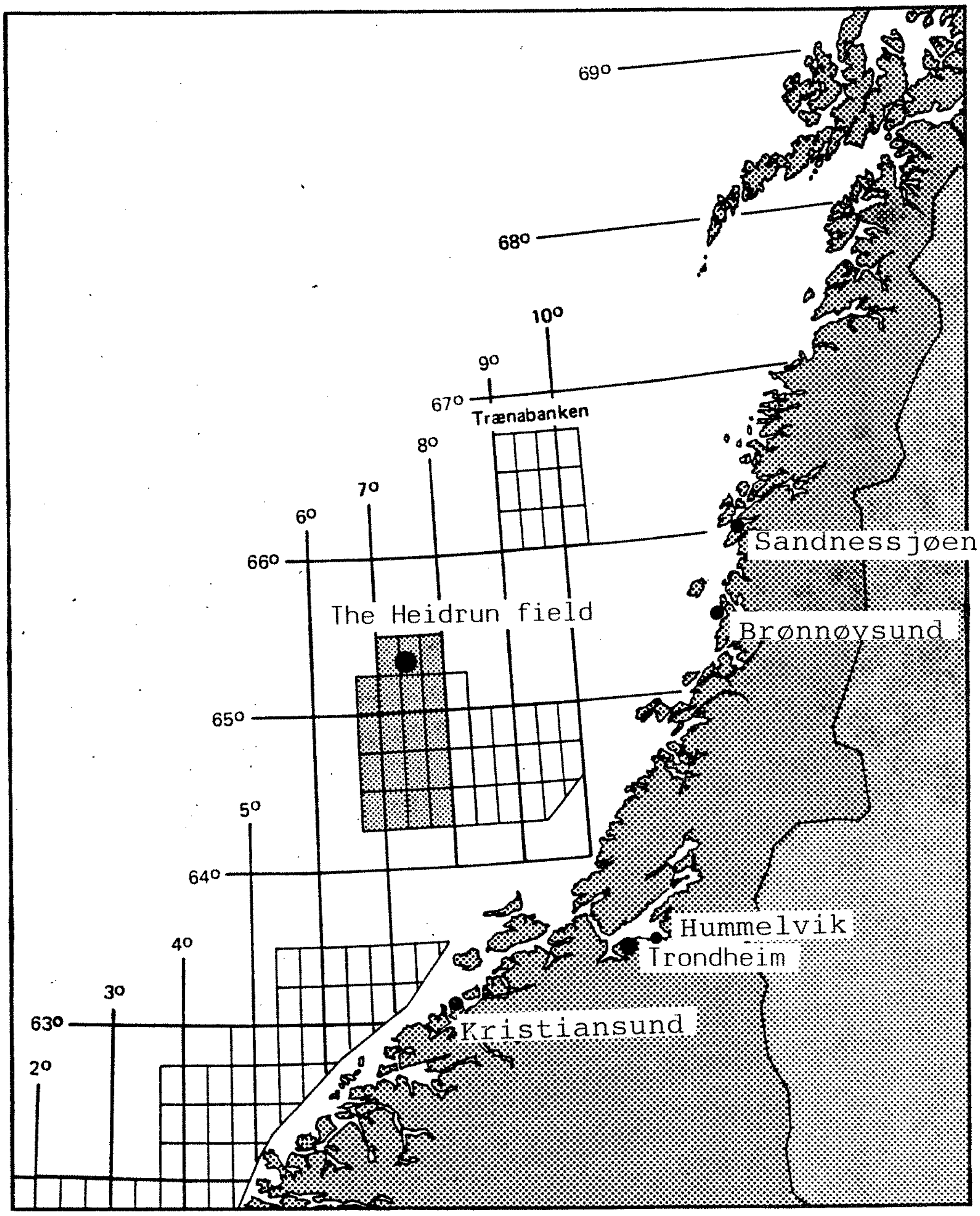


Fig. 2.1. Map showing the Heidrun field and potential locations for operation, supply and helicopter bases.

2.3. PHYSICAL SOURCES OF EFFECTS

The following points present the physical sources of effects.

A. Physical presence of platform and pipelines - losses of access to fishing grounds and artificial reef effects.

The safety zone surrounding the Heidrun field platform will be equivalent to 0.8 km^3 (radius = 500m). A pipeline from the Heidrun field to Draugen will, because of its size (>20"), not be trenched. Uncovered pipelines may obstruct traditional fishing operations and beam and ottertrawls activity in the vicinity of pipelines may increase the possibility of pipe rupture (de Groot, 1975).

B. Physical presence of objects left on the sea floor.

During the construction, commissioning and operation phase it is possible that objects may be dropped from the platform or nearbay vessels/barges. Under Conoco's environmental policy all possible precautions will be taken to prevent these occurrences. Contractors involved in the Heidrun field are contractually obliged to avoid the disposal of debris on the sea floor. Any significant objects that are accidentally dropped will be removed.

C. Anchoring of construction vessels and pipeline construction.

This may cause some seabed disturbance within a limited distance (<30 m) of the anchors and pipelines, resulting in increased mortality of benthic fauna. The effects will be difficult to detect, time limited and tied to a limited seabed area.

D. Building of operation, supply and helicopter base.

The building of these facilities are regulated by local laws for landbased activities.

E. Marine supply activities caused by supply ships.

These activities may potentially increase the possibility for conflicts between supply and fishing activities and may result in some disturbance of seals and birds.

F. Helicopter traffic noise.

Helicopters may disturb seals and birds if they fly near breeding colonies.

G. Noise from drilling activities.

Seals, whales and fish use auditive information for behaviour purposes. Noise from drilling and platform activities may influence the behaviour of these animals.

H. Cooling water discharge.

Temperature is a fundamental parameter for all biological activity and discharge of water with increased temperature may thus potentially affect marine life. The discharge of cooling water in the Heidrun field is expected to be limited and will not influence significantly any of the components considered in this report.

I. Flares.

Burning of gas result in light emission. During the night this may attract some birds which may die or be injured because of the heat in the flare.

2.4. CHEMICAL SOURCES OF EFFECTS

Accidents.

A. Blowout followed by oil spill.

Experience from other areas has shown that irrespective of efforts to avoid blowouts they may occur. Such uncontrolled discharge of oil may result in large amounts of oil in the sea. A worst possible case in the Heidrun field context is a discharge of 200 000 barrels per day. The oil may be transported by winds and currents to other areas.

B. Rupture of a submarine pipeline followed by a subsurface oilspill.

Rupture of a pipeline may be caused by technical failure of the pipeline or physical damage caused by fishingear etc. A subsurface rupture causes relatively high amounts of the volatile components to be dissolved/dispersed in the water column. Still a large portion of the oil will reach the surface and be transported to other areas by wind and currents.

Normal activities.

C. Discharge of drill cuttings and drilling mud.

During the development of the Heidrun field a total of 53 wells will be drilled, 38 from the platform and 15 from additional subsea units over a period of 2-3 years. The maximum amount of oil allowed in drilling mud is 10 %. A low toxicity oil based mud will be used. The mean volume of cuttings from drilling of a well will be on the order of 450 m^2 with a density of 2 kg/dm^3. The cuttings cleaning procedure adopted will depend on the type of platform used. Cuttings cleaning alternatives are (1) for a tension leg platform: cuttings will be shipped ashore and disposed on land; (2) for a Condeep platform: cuttings will be cleaned using primary shakers and centrifugation. Cuttings with adhering mud will be discharged into the sea at the Heidrun field.

D. Oil in production and formation water.

The maximum amount of hydrocarbons allowed in discharges of production and formation water is 40 ppm. The assumed discharge of production and formaion water in the Heidrun field is shown in Table 2.2.

E. Additives in production and formation water, heavy metals in formation water, biocides, anti-oxidants etc.

F. Sewage and other domestic wastes.

Sewage from the personell modules (350-280 persons) will be discharged without treatment to the sea.
There has recently been a concern about the oxygen demand (OD) caused by the hydrocarbons in the effluents and the possible contribution from this to increased eutrophication. This could

be a problem in environments with limited water exchange or where eutrophication already is a problem, but is not likely to be significant on an offshore site as the Heidrun field.
The oxygen demand caused by the proposed discharge of production and formation water is shown in Table 2.1.

G. Additives in water discharged after pipeline pressure testing.

There is a number of chemical compounds found in solution in effluents from offshore oil platforms during normal activities. Ecological effects of these compounds have been reviewed (Middleditch, 1984). It was concluded that current procedures for the disposal of produced water are ecologically sound, and that the concentration of individual components of produced water found to be responsible for sublethal effects in laboratory experiments, are unlikely to be encountered in the vicinity of offshore production platforms beyond the mixing zones surrounding the outfall.

In the assessment of effects from chemical compounds it is thus imperative to focus on possible environmental effects arising from accidents and from discharge of drill cuttings.

Table 2.2. Assumed discharge of produced water, ballast water and oil from these sources. Estimated amount of oxygen consumed assuming all the discharged oil is degraded completely by oxidation is also calculated (Conversion factor Oil/oxygen = 3.5, See Atlas 1981). Amount of water = 10^6 tonnes. Amount of oil and oxygen = tonnes.

	Years				
	1992	1993	1994	1995	1996
Produced water		0.02	0.06	0.47	1.3
Quantity of oil		0.63	2.6	17.8	48.3
Ballast water	2.3	7.5	12.4	12.4	11.2
Quantity of oil	54.7	179	249	295	266
Total water	2.3	7.5	12.5	12.9	12.5
Total oil	54.7	180	297	313	314
O_2 consumption		51	85	89	89

Table 2.2. continued

	1997	1998	1999	2000
Produced water	3.2	5.1	5.1	4.0
Quantity of oil	125	192	194	153
Ballast water	12.2	10.2	8.2	6.1
Quantity of oil	289	243	195	145
Total water	15.4	15.3	13.3	10.1
Total oil	414	435	389	298
O_2 consumption	118	124	111	85

2.5. METHODS USED IN EFFECT ASSESSMENTS

Two distinct strategies have been employed in attempts to discern the ecological effects of offshore operations: predictive and observational. The predictive approach involves determination of the effect of a specific physical or chemical perturbation based on some sort of experimentation. The results of these experiments are later related to the expected distribution and the level of the perturbation in the environment.

The observational approach is based upon actual measurements of impacts after an incident which in most cases is not planned (eg.oil spill). The difference between the two approaches is that the observational is site specific while the predictive is not. In the predictive approach the experimental conditions are defined in detail whereas this is seldom possible under the observational approach. In the evaluation of the possible environmental consequences of offshore operations the predictive approach is applied. However experience aquired from unpredictable incidents in a similar area may be used as a predictive tool, thus, the distinction between the two approaches becomes less clear.

2.6. FIELD FACILITIES - HEIDRUN FIELD

A single platform will be used in the Heidrun field. The two alternatives are a tension leg or a Condeep platform. For both alternatives the platform will consist of modules for accommodation of personnel, drilling, oil production and storage. Offshore loading to tankers or a pipeline will be used for transportation of produced oil.

During the development of the field the platform will house approximately 350 persons and in the production phase 280-300 persons. The platform will be serviced by supply vessels.

2.7. OPERATION OFFICE, SUPPLY AND HELICOPTER BASE

The location of these facilities are not yet decided. Four alternatives are suggested (see Fig. 2.1).

1. Operation, helicopter and supply base in Throndheim. This alternative involves building of a quay in the Hummelvik area.

2. Operation, helicopter and supply base in Kristiansund. No additional quays will be built.

3. Operation base in Trondheim. Supply base and helicopter base in Kristiansund. No additional quays will be built.

4. Operation base in Trondheim, helicopter base in Brønnøysund and supply base in Sandnessjøen.

The distance from the Heidrun field to the four alternative locations is approximately 50 nautical miles (Heidrun-Trondheim: 52, Heidrun-Kristiansund: 49, Heidrun-Brønnøysund: 46, Heidrun-Sandnessjøen: 50)

The frequency of supply ships to the platform will be 2-3 per week in addition to the stand-by ship which usually will be stationed in the platform area one month at a time. Transport of personnel to the platform will be performed 1-2 times per day.

3. OFFSHORE ENVIRONMENT

3.1. OFFSHORE ENVIRONMENT - GENERAL

For the purposes of this assessment it is necessary to define the extent of the offshore environment. Since the area of study is three dimensional three bounderies have generaly been used. The upper boundary is normaly taken as the air/sea interface. Seabirds do of course move above the water surface but are most likely to be influenced near or on the surface. The lower boundary is defined by the level within the bottom sdiments below which sediment characteristics are not influenced by natural environmental fluctuations. The boundary between the "offshore" and "inshore" environment is defined by a line ("grunnlinjen" refered to as base in the figures) drawn along the coast outside all islands and skerries.

Most biological processes and biotic components in this environment result from, are located to, or are dependant on phenomena in or near the air/water interface and the sediment/water interface. This is reflected in the distribution of particles in the sea which is highest near the surface and the bottom.

The presence of hydrocarbons in the ocean is not a new and antropogenic phenomenon. Conservative estimates indicate that 10 million tonnes of biogenic hydrocarbons are yearly produced by marine algae in the marine environment. One million tonnes of petroleum hydrocarbons originate from natural oil seeps and 6 million tonnes from human activity. As early as 1975 lumps of tar were found in surface waters all along the Norwegian coast and also in the Barents Sea (Smith, 1975). In effect none of the oceans are free from petroleum hydrocarbons.

Products released to the sea will float, sink or stay in solution depending on density and solubility. The density of oil will generally increase with evaporation and solubility will increase for photo-oxidated components. Generally only a fraction (see Fig.3.2.5) of an oilspill will eventually reach the sediment/water interface. The solubility of petroleum hydrocarbons is also low. This means that the potential effect of oil in the offshore environment is basically confined to the surface (0-20 m) whereas other aspects of offshore activity like discharge of cuttings, mud and laying and trenching of pipelines are primarily confined to or affect the sediment/water interface. In effect offshore activity potentially affect processes and biotic components near or in the two major interfaces of the ocean

- surface and bottom.

The challenge in environmental impact assessments offshore is not just to make predictions, but also to make accurate predictions, implying that they can be tested. The offshore environment potentially affected by the Heidrun field development stretches along the Norwegian coast from Møre and Romsdal to slightly north of the Lofoten area (See Chapter 4 for oil spill modelling) and thus encompasses an immense body of water. This body of water is in a state of dynamic equilibrium meaning that the area is continuously supplied with oceanic water from the Atlantic and more low salinity water from river runoff and the coastal current. In the potentially affected area, the current system may form gyres resulting in accumulation of suspended material and a lager retention time than otherwise expected in other areas.

Most predictions of impact on elements of this huge system are based on certain assumptions concerning physical phenomena (drift of oil, evaporation, vertical mixing, sedimentation etc.). Predictions are, thus, in effect second-order predictions. The confidence in predictions generally decreases with longer time scales (effects on future catches of fish) and distance from the source of impact. The variability of most marine biological populations is so great that we cannot hope to distinguish man-induced, low level effects. In effect variability is generally the rule for marine populations. Predictions on possible environmental effects are in reality based on professional judgement and educated guesses based on sientific studies and experience from other areas.

3.2. PRIMARY PRODUCTIVITY

3.2.1 Introduction

The phytoplankton are the only organisms that can produce new organic matter in the offshore environment. The phytoplankton as well as the seaweeds are able to restore energy as sugar compunds from CO_2 and water utilizing the sun as energy source - the process of photo-syntesis. On a global basis the production in the marine environment is 24.8 billion tons carbon (C) on an area of $361x10^6$ km^2 of which 99% is produced by phytoplankton. Theoretically this gives rise to about 210 millions tons carbon as fish stock (Akenhead et al., 1979). The continental shelf areas are very productive giving 4.3 billion tons carbon pr. year, i.e. 17 % of the total yield, over just 7 % of the total marine areas (Woodwell, 1978).

The primary production is expressed as produced organic carbon pr. area and time, usually g $C/m^2/year$ (or day). The phytoplankton are essential for all living life in sea - being at a lowest, hence basic, trophic level. On a higher level one finds the grazers, usually zooplankton (primary consumers K_1) feeding on phytoplankton, utilizing some of the energy for growth. These herbivores are the prey for carnivorous zooplankton (secondary consumers K_2) and on the top of the marine hierarchy one finds fish (tertiary consumers K_3), birds and mammals.

It is obvious that from the available energy from the sun: 250000 $kcal/m^2/year$, only a fraction reach the top predators: 0.7 $kcal/m^2/year$ (Hylleberg, 1978). Another way to describe the utilization of carbon between the different trophic levels are described in Fig. 3.2.1. From a production of 100 g $C/m^2/year$ from the pytoplankton, only 0.1 g $C/m^2/year$ is found in the fish (Hylleberg, 1978). Hence, it is a substantial amount of carbon required to produced the yearly outcome from fisheries. One ton of carbon produced by phytoplankton can theoretically give rize to 1-2 kilos of carbon as fish.

3.2.2. Plankton communities in the Heidrun influence area

Phytoplankton

As planktonic organisms are defined as not being able to perform significant horizontal movement by swimming they are bound to follow predominant currents. The zooplankton, however, are able to migrate up

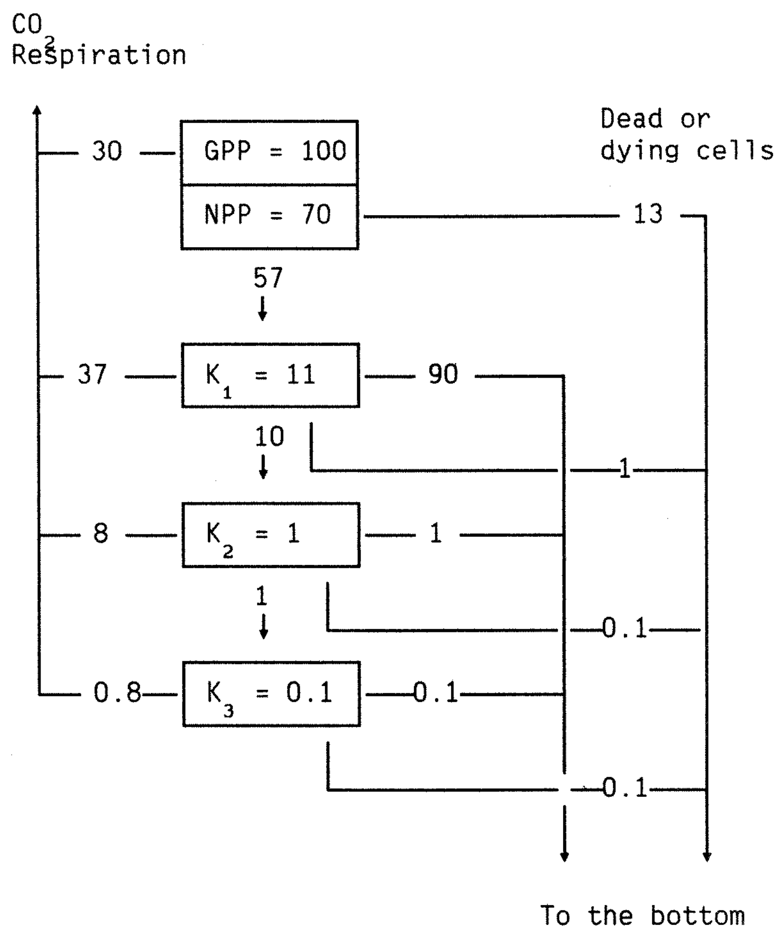


Fig. 3.2.1. The flow of carbon through the pelagic system.
GPP = Gross Primary Production
NPP = Net -"- -"-
K1 = Secondary production i.e. mainly zooplankton.
K2 (+K3) = Tertiary production i.e. K3 is feeding on K2 which again feeds on K1.

and down in the water column. As the currents can show distinct opposite directions at different depths zooplankton can stay in a certain area for a longer time than the phytoplankton. Along the area considered in this report the prevailing suface currents in the Haltenbanken coastal region are indicated in Chapter 4 (Fig. 4.1). Except for some large areas of virtually no residual currents, the prevalent current flows along the coast and along the continental shelf northwards.

The phytoplankton in the area from Sunnmøre to Helgeland has been well described, quantitatively as well as qualitatively, from the beginning of this century as a part of surveys estimating fish stocks. Primary production and biomass as chlorophyll-a has also been performed on spring bloom situations by the Marine Research Institute in Bergen since 1968. These results show a considerable range in daily production rates. A typical example, from April 1976 (Fig. 3.2.2), shows that the areas around Haltenbanken and Sklinnabanken are highly productive with production maximum of 1.6 and 2.8 g C/m^2/day, respectively. In coastal areas the production was about 0.4 g C/m^2/day. The production rates also show considerable variation during the year. Based on 5 surveys during 1976 the calculated yearly production was between 55 and 100 g C/m^2/year.

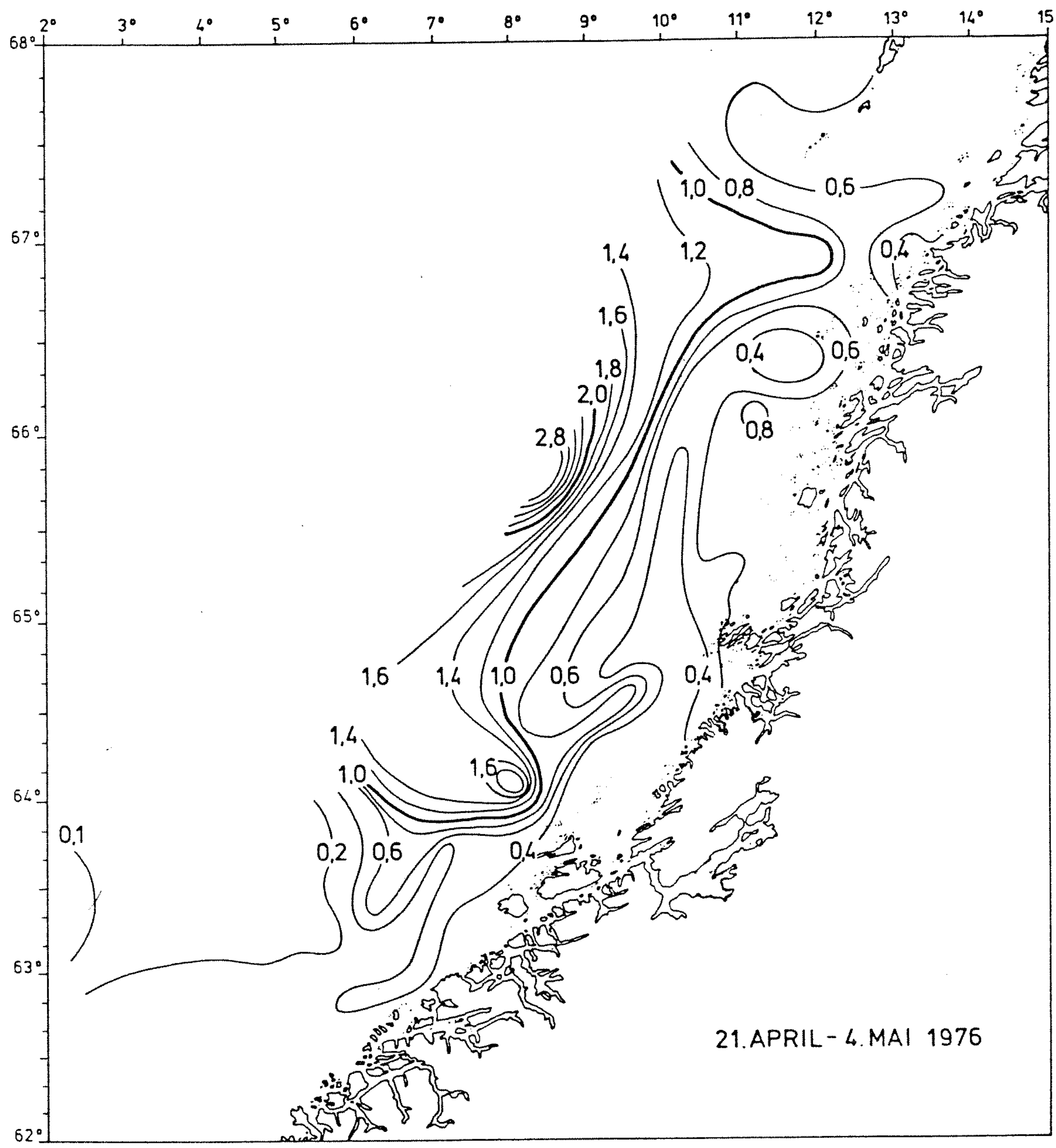


Fig. 3.2.2. Rates of primary production in g C/m^2/day. (Anon 1979)

The highest primary production is found at the fishing banks and close to the coastline, the lowest outside the shelf and between the fishing banks (Anon 1979). The production rates seem to peak in spring, decrease significantly during summer to show a minor peak again during fall. This is the typical pattern for the area from Haltenbanken and northwards, Fig. 3.2.3. The mean daily production rates offshore at Haltenbanken seem to peak somewhat earlier than the coastal areas (Anon 1979). The percent production over the year also show that the production at the fishing banks is concentrated more to the spring period (60%) i.e. just before the period of animal spawning. The coastal areas show a 40-40-20 percentage distribution during spring-summer and fall.

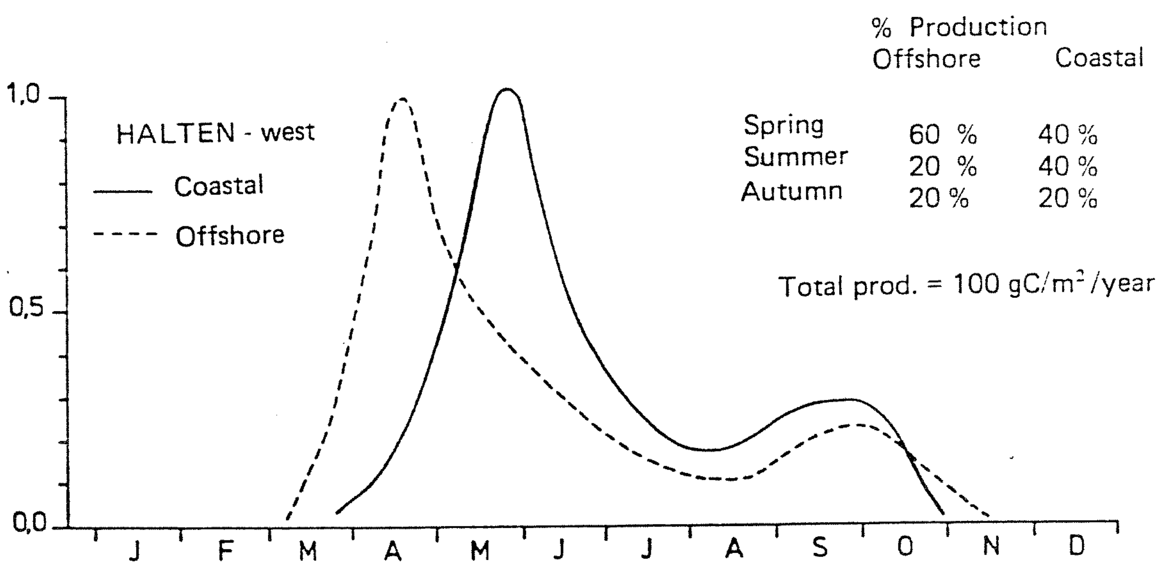


Fig. 3.2.3. Yearly pattern of intensity in primary production rates at Haltenbanken - west (Anon 1979).

Zooplankton

As an example of the distribution of zooplankton Fig. 3.2.4 shows the distribution pattern in the upper 100m along the coast during May/June 1975. The Haltenbanken area appeared to have large stocks of zooplankton exceeding 100 ml/m^2 The map shows a distinct patchiness of plankton which is also thought to be a general trend. As the zooplankton consists of mainly primary consumers feeding on the phytoplankton, they are considered to obtain a successful growth only where there is sufficient phytoplankton available. Hence, evaluation of oil effects on phytoplankton will also reflect effects on zooplankton.

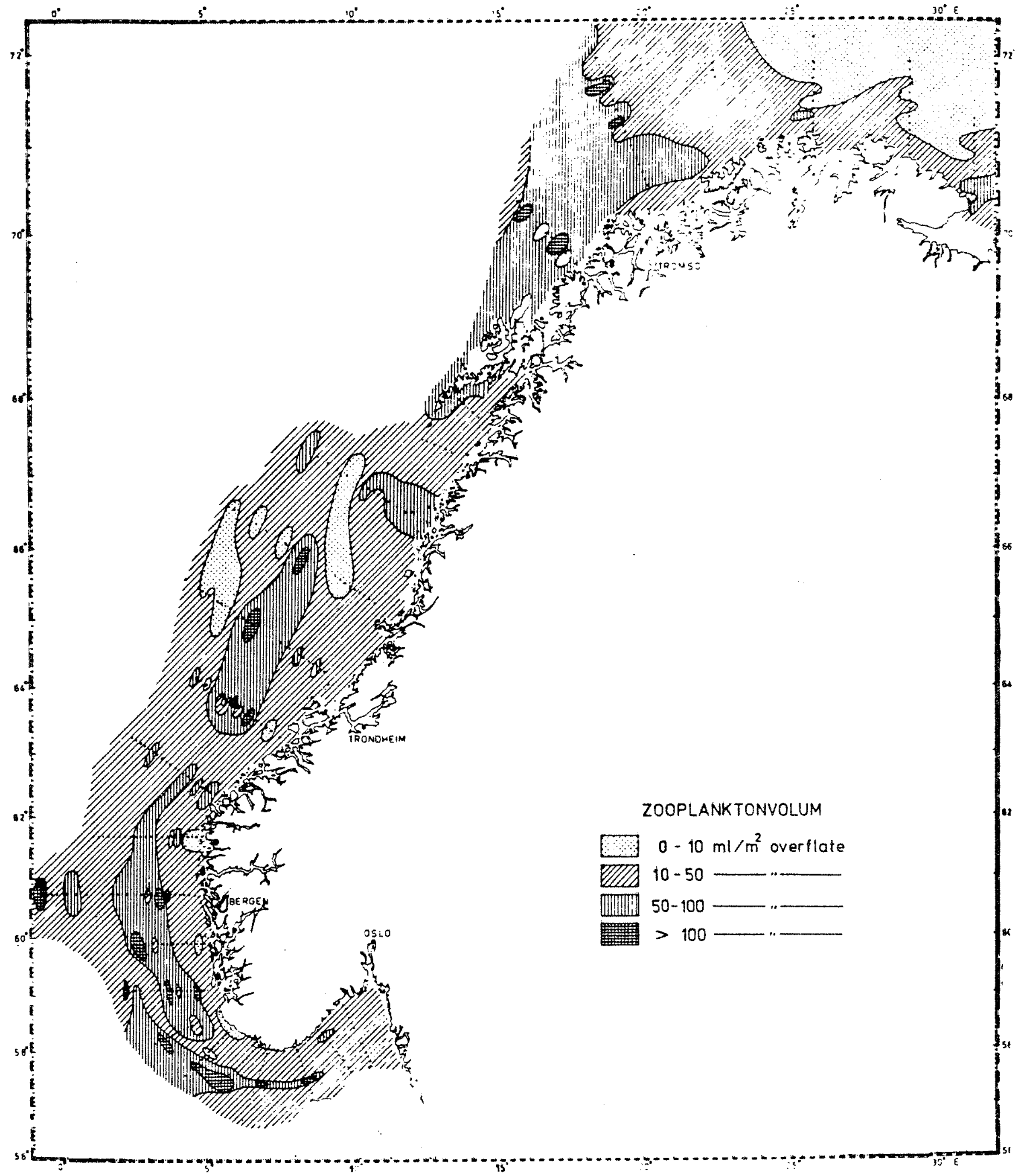


Fig. 3.2.4. Distribution of zooplankton in the upper 100 m along the coast during May 24 - June 3, 1975 (Anon 1979).

3.2.3. Fate of an oilspill in relation to primary production

Before discussing the impact of an oil spill, it is useful to review briefly the behavior of a "typical" oil spill. In offshore environment the dominant processes determining sites of impact are horizontal spreading and drift rate. These processes are discussed in Chapter 4. Of particular concern from an environmental viewpoint are the processes of evaporation, dissipation, dissolution, dispersion, biodegradation and sedimentation. These prosesses are dependent on type of oil and the type of oil accident. The two basic types of scenarios are: subsurface release of oil and gas and surface spill of oil. The fate of the oil under these two circumstanses are quite different.

In the event of a bottom release there is turbulent contact between the rising oil and gas and the water column with the potential for considerable dissolution and emulsification. A plume of oil and gas rises to the surface and sets up a circulation pattern which may convey surface oil back into the water column (Mackay, 1985). This was the case for the "Ixtoc" blowout. The turbulent mixture of oil and water on the way to the surface means that the toxic substanses are easily dissolved in the water column as opposed to a surface spillage where a large fraction of the light and toxic aromatic compounds are evaporated.

If the discharge is at the sea bottom, however, the aromatic fraction is dissolved to some extent below the euphotic sone. In our waters the primary production can only take place in the upper 30 to 50 meters, hence, water masses below these depths are not as crucial for the primary production.

The surface spillage situation results in another process of mass balance of the oil. Fig. 3.2.5 gives a speculative mass slick balance. Within the first day a large percentage of the oil is lost by evaporation. It is the most volatile fraction that evaporates i.e. lighter aromatics which are also the most toxic compounds in crude oil. After about a week evaporation has ceased as well as the dissolution of oil into the water.

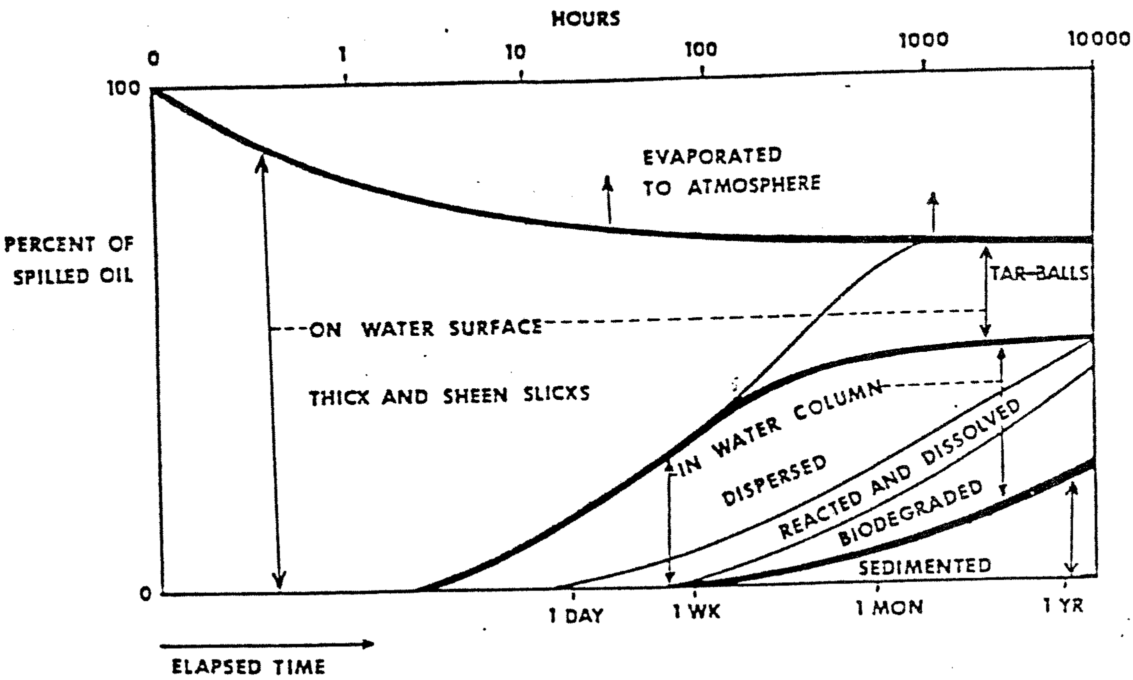


Fig. 3.2.5. Speculative mass slick balance after an oil spill (Mackay et al., 1983).

3.2.4. Effects of oil on primary production

A considerable number of results have been published on effects of oil on seaweeds, phytoplankton and primary production. In general the impact on the pelagic system is a relatively short term effect. This is illustrated in Fig. 3.2.6. where the impact on the pelagic zone after the "Tsesis" spill, was barely detectable after one month (Lindén et al. 1979). Based on oil spill from "Argo Merchant" and "Amoco Cadiz" Vandermeulen (1982) concluded that if an oil slik moves offshore into deeper waters immediately after discharge as after "Argo Merchant", contamination of the water column is relatively shortlived. However, with an "Amoco Cadiz" type spill, when slicks persist in shallow water areas, there is increased chance of water column contamination. The short term hydrocarbon concentrations that can be expected during a spill are in the range 10 to 200 ppb (an exception- "Arrow-oil spill" max. 700 ppb).

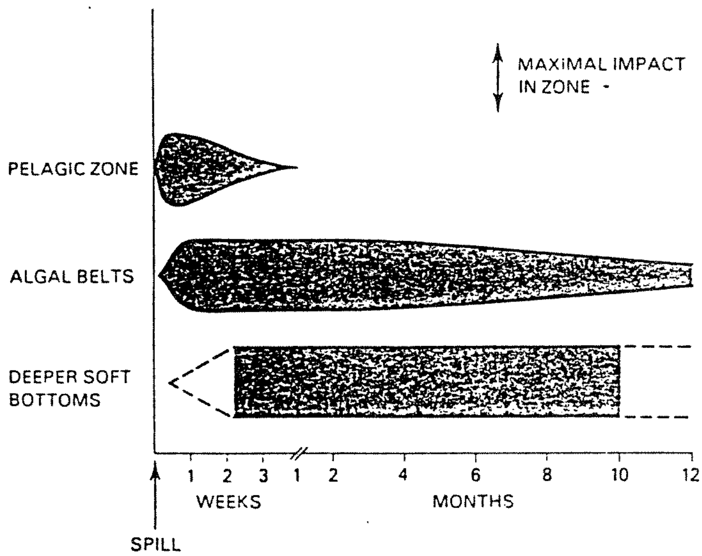


Fig. 3.2.6. Duration and intensity (relative scale) of ecological disturbance following the "Tsesis" oil spill in the three major biotopes studied. (After Linden et al., 1979).

From the blowout at Bravo in the North Sea no significant negative effect on primary producers was detected. A slight tendency of increased production was found, but in contrast to earlier findings by Gordon & Prouse (1973) no differences in impact among different size fractions of producers were found (Lännergren, 1978).

Vandermeulen and Ahren (1976) have given a review on the effects of oil on algal physiology. The findings can be summarized as follows:

1. *Retardation of cell growth.*
2. *Inhibition of DNA and RNA activity at high oil concentrations.*
3. *Different susceptibility to oil for different species.*
4. *Change from large diatoms to small monades.*
5. *Aromatic compounds as benzene, toluene, phenathrene, naphthalene, cresol, trimethylbenzene, methyl naphthalene and dimethylnapthalene showed strong negative effect on phytoplankton.*

Major negative effects on primary production have been reported mainly from experimental work. Many of these works have been reviewed in Vandermeulen & Ahren (1976), O'Brien & Dixon (1976) and Johnson (1977). In situ registration has not been able to verify such negative impact as described from laboratory or field experiments with a water column enclosed in bags. A reduction in primary production have been documented at concentrations of 200-300 ppb in plastic bags (Anon 1984 (FOH)) . The lowered primary production appeared, however, to be mainly an indirect effect og a reduced excretion of nutrients from zooplankton as well as shading effects of the oil slick (Anon 1984(FOH)).

In contrast increased primary production have been reported from impacted areas (Johanson et al., 1980, Lännergren, 1978) In some laboratory studies especially at low hydrocarbon concentrations (50-100 ppb), stimulating effects have been reported by several authors (Gordon & Prouse, 1973, Parsons et al., 1976, Prouse et al. 1976, Hiaso et al. 1978.)

3.2.5. Criteria for level of impact

Under the Norwegian Marine Pollution Reseach and Monitoring Program - FOH (case 27/78) a group of experts prepared a generalized assessment of the likely worst case impact of offshore oil spills on Norwegian fish production and yield. Consideration on the lower trophic levels was included. The group considered oil older than 15 days to be harmless to life below the slick. They also cautiously concluded that hydrocarbon levels above 50 ppb are only found under visible surface oil.. Such enhanced oil concentration might be found down to the termocline. Furthermore as a worst case scenario, it was assumed that all plankton, eggs and larvae in the water column under an oil slick less than 15 days old were to be considered as lost. The criteria applied are listed in NOU nr.25 (Anon. 1980).

In the light of today's knowledge, the conclusion that eggs and larvae will be lost under the area covered by 15 days old oil is too restrictive and the FOH final report (Anon 1984(FOH)) concludes that :

1. *Oil older than 5 days is considered non-toxic.*
2. *Hydrocarbon concentration below 50 ppb in the water is harmless.*

These are the two criteria used in the present report for the impact on the primary production.

3.2.6. Areas of influence

Based on the rates of movement of oil in the spill modelling (Chapter 4) areas with oil of various ages during the different seasons have been estimated (Table 3.2.1). It shows the potential area covered by 1, 5 and 10 days old oil in a blowout situation of 120 ton/hour. The drift model is based on a spring, summer, fall and winter situation The mean drifting time is based on an average of all the simulated oil patches and it is clear that the area covered by one day old oil under these conditions are negligible. The possible area covered by 5 days oil varies from 150 km^2 in summer to 7870 km^2 during winter. It must be pointed out that a winter situation is not further considered in this report as there is no significant primary production in this period due to insufficient light conditions. After 10 days the range of area of possible influce is from 7210 to 48060 km^2.

The areas covered by oil at minumun drifting time are considerably larger. The area where 1 day old oil may be found can cover up to 5300 km^2. The corresponding area for 5 days old oil may be up to 86 000 km^2. The percentage oil remaining at the surface in the fringe of the areas is also shown in Table 3.2.1.

Table 3.2.1. Potential area covered by 1, 5, and 10 days old oil in a blowout situation of 120 tons/hour during 3 months periods. The percentage figures indicate maximum surface oil found in fringe areas. Position of blowout 65°20'N, 7°19'E. The drift model is based on wind and current data from 1955-1981. Density of the crude oil 900 kg/m^3.

3 months blowout periods	Area covered (km^2) and amount of oil found in the respective area based on Mean drift time			Area covered (km^2) and amount of oil found in the respective area based on Minimum drift time		
	1 day	5 days	10 days	1 day	5 days	10 days
SPRING						
Mar-May	-	1.480	19.680	5.260	86.320	189.140
Amount of surface oil in the respect. area	>50%	~45%	25%	~60%	~25%	~10%
SUMMER						
June-Aug	-	150	7.210	2.960	50.270	121.200
Amount of surface oil in the resp. area	-	>50%	~35%	~65%	~35%	~20%
AUTUMN						
Sept-Nov	-	3.590	25.720	5.060	84.4	199.140
Amount of surface oil in the resp. area	-	~40%	~20%	~60%	~25%	5-10%
WINTER						
Dec-Feb	-	7.870	48.060	5.980	98.600	204.010
Amount of surface oil in the resp. area		~30%	10-15%	~60%	~20%	5-10%

Table 3.2.1 gives the largest possible influenced areas during the four seasons based on statisitcal drift trajectories in three months periods. The real area of the oil slick after 1, 5, 10, etc. days will be far less. A ratio between the area of a slick from a single spill and the area within which the oil is likely to be encountered is suggested in Figure 3.2.7. This indicates that the 'real' area covered by 5 and 10 days old oil is respectively 1/30 and 1/10 of the area within which the slick is likely to be found.

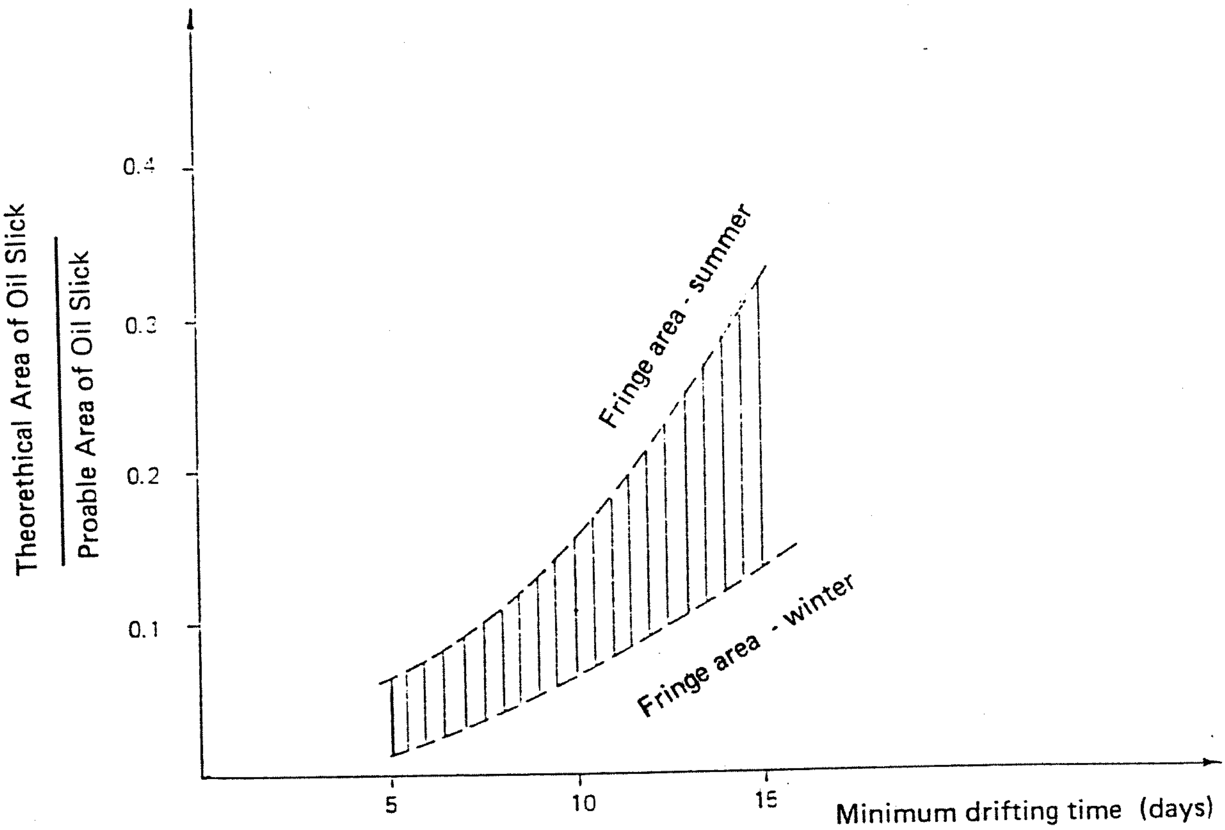


Fig. 3.2.7. Ratio between probable and theoretically possible area covered by an oil slick within 5, 10 and 15 days minimum drift time (Anon. 1978).

In Table 3.2.2 the estimated 'real' areas likely to be influenced by oil have been recalculated on basis of Figure 3.2.7. The area covered during a period of 5 days and thereby thought to be lost is only 50km^2 during spring (see. Tables 3.2.3 and 3.2.1.), which is the most sensitive period. Corresponding areas during summer and autumn are 5 and 120 km^2 repectively. For a worst case situation the areas lost during spring, summer and fall would be 3000, 1700 and 3000km^2 respectively.

Table 3.2.2. Areas covered by oil slick and estimated loss in primary production during mean drifting time and minimum drifting time and 1, 5 and 10 days blowout within each season. A = Maximum area theoretically covered (see Chapter 4.). B = Probable area covered by oil slick (based on Fig. 3.2.9). C = Total loss of primary production within area B in tons carbon for an offshore production area and a coastal primary production area. n.c. = not calculated/ impossible to calculate.

	Mean drift time			Minimum drift time		
	1 day	5 days	10 days	1 day	5 days	10 days
SPRING						
A Max possible area influence (km^2)	negligible	1.480	19.680	5.260	86.320	189.140
B Area likely to be influenced (km^2)	n.c.	50	2.000	n.c.	3.000	19.000
C Estimated loss of primary production in tons during 3 months period						
Offshore area	n.c.	3.000	n.c.	n.c.	180.000	n.c.
Coastal area	n.c.	2.000	n.c.	n.c.	120.000	n.c.
SUMMER						
A	negligible	150	720	2.960	50.270	121.200
B	n.c.	5	70	-	1.700	12.000
C Offshore area	n.c.	100	n.c.	n.c.	35.000	n.c.
Coastal area	n.c.	200	n.c.	n.c.	70.000	n.c.
AUTUMN						
A	negligible	3.590	25.720	5.060	84.440	199.140
B	n.c.	120	2.600	n.c.	3.000	20.000
C Offshore area	n.c.	2.400		n.c.	60.000	
Coastal area	n.c.	2.400		n.c.	60.000	
Mean estimated influenced (km^2)	n.c.	~60	~1.600		2.600	17.000

The latter calculations are based on the fate of a single slick. In the case of a continuous discharge the 'real' areas would be larger but difficult to calculate. Another approach is to base estimates of impact areas on the likely dissipation of oil in the water and how much water which is needed to dilute this to less than 50 ppb.

The rate of dissipation changes with time and speed of wind. At winds of 8.5m/s and 20m/s the following percentage of oil is dissipated (Based on Mackay 1985, Anon 1984 (FOH) and Chapter 4):

8.5 m/s	1 day	- 12.7%
	5 days	- 32 %
	10 days	- 45 %
20 m/s	1 day	- 53 %
	5 days	- 60 %
	10 days	- 65 %

Based on these dissipation rates one can calculate the volume of water needed to dilute the amount of spilled oil being less than 5 and 10 days old during a continuous blowout (120 tons/hour) to less than 50 ppb. As the oil is thought to be diluted down to a depth of 30 m (the mixed zone), the area under which 50 ppb occur can be calculated (Table 3.2.3). At 8.5 m/s wind speed and oil not more than 5 days old, the area of sea necessary to dilute the dissipated volume of the oil to less than 50 ppb would be 3000 km^2. This is a larger area than shown for the same spill in Table 3.2.1. Hence the area necessary to give less than 50 ppb in the water column will during spring and summer exceed the calculated maximum area where 5 and 10 days old oil may be found. This implies that the water column in the possible influenced area during spring and summer (Table 3.2.1.) may have hydrocarbon concentrations above the 50 ppb level.

Likewise, the area necessary to dilute the dissipated portion of 10 days of discharge to 50 ppb will be about 9000 km^2. This is less than the area within which 10 days old oil is found in spring and fall, but not in summer, i.e. concentrations above 50 ppb would be encountered in summer.

It is important to stress that these theoretical calculation are worse than the real situation as one has considered all the oil as being toxic and no biodegradation has been taken into consideration.

Table 3.2.3. Areas covered by 50 ppb oil/seawater concentration down to 30 m depth during blowout duration of 5, 10, 30 and 90 days. The areas are based on different dissipation rates: 5 days oil oil: 32 and 60% of total oil spill at 8,5 and 20 m/s wind respectively and 45% and 65% for 10 days old oil at 8.5 and 20 m/s wind respectively.

Drifting time	Duration of blowout	5 days old oil cover: (km^2)	10 days old oil cover: (km^2)
Mean drifting time	5 days	3000	-
	10 days	> 3000	9000
	30 days	> 3000	> 9000
	90 days	> 3000	> 9000
Minimum drifting time	5 days	6000	-
	10 days	> 6000	13000
	30 days	> 6000	> 13000
	90 days	> 6000	> 13000

3.2.7. Loss in primary production

Based on the estimated areas likely to be influenced (table 3.2.2) and the relative production figures given in Fig. 3.2.4 it is possible to give a rough indication of what amount of carbon or energy is lost by the different oil spill situations. These are found in table 3.2.2. and are calculated for the two areas offshore and near coastal areas, which showed to have a shift in timing of the production peak (see section 3.2.2). The values during the sensitive spring period are for offshore areas 3000 tonnes carbon for mean rate of oil drifting and 180 000 for a worst case. If one uses the somewhat speculative equation of Akenhead (1977) (in Vandermeulen 1982), stateing as a rule that the relationship between primary production and fish yield is described approximately by the linear equation:

Fish yield = 0.0021 x Primary production

(the denomination is in g C/m^2/year), the loss of fish would be 0-380 tonnes carbon as fish i.e approximately 0-4000 tonnis fish. Such losses are within the natural variation in fish production, hence the effects on fish is not apprehensious. The fish caught during spring in the influence area inside 12 n mile zone only, was in 1984 about 100.000. tonneis fish (table 3.3.4).

3.2.8. Conclusions

An oilspill of 120 tons/day where the oil for the first 5 days oil will discharge compounds toxic to the plankton, will cause some loss in the primary production.

The roughly estimated losses in tons of carbon are not substantial and will not have any severe effects on the primary production as the variation in production from one year or site to another is greater. The direct repercussion of an isolated loss in primary production on the higher trophic levels including fish, is not considered serious.

Whether or not an oil spill in the Heidrun field will change the species composition in the phytoplankton communities is not possible to predict, but significant changes are not likely as the period of impact on one particular body of water is short.

It is not likely that normal operation of the field will cause any significant effect on the primary production.

3.3. FISH STOCK AND LARVAE

3.3.1 Introduction

The Norwegian continental shelf and especially the continental edge is an area with large fish resources (Fig. 3.3.1). Haltenbanken is especially important because the area contains spawning and nursery grounds for commercially important species. The landing of fish from the Haltenbanken area is also significant (Fig. 3.3.2).

A prominent feature of the Norwegian coastal current is that it enforces species with pelagic egg and larvae to perform countercurrent spawning migrations in order to compensate for the drift of eggs, larvae and juveniles. The coastal current may also both transport and accumulate oil which are spilled to the sea offshore.

Important species which spawn or have nursery grounds in the Haltenbanken area are cod, saith, haddock, herring, place, red-fish, ling, torsk, great argentin and crabs. Some of these species are at present not important for the fishery in the Haltenbanken area (see Fig. 3.3.2), but may be important in other areas. Other species like herring were until 1969 commercially extremely important but are at present only significant locally because of reduced stock due to overfishing.

Offshore operations may potentially affect fish populations through increased mortality of adults, eggs and larval stages due to toxic compounds in different types of discharges. The vulnerability of the different species should ideally be judged from basic biological data and toxicology for eggs, larvae and adults with special reference to spatial overlap (horizontal and vertical) between different life stages and a potential discharge of oil or other chemicals from offshore activities.

The general large scale horisontal distribution of the different life stages of the commercially most important fish along the Norwegian coast is known. For a specific point in time, however, the distribution is to a large extent determined by the prevailing hydrographic conditions (Ellertsen et al., 1981). Thus the distribution of fish can a priori not be estimated accurately. The oil-spill model is two-dimensional, statistical and predicts the probability of oil reaching a specific area and the time needed . For fish it is not the oil on the surface but the content of oil in the

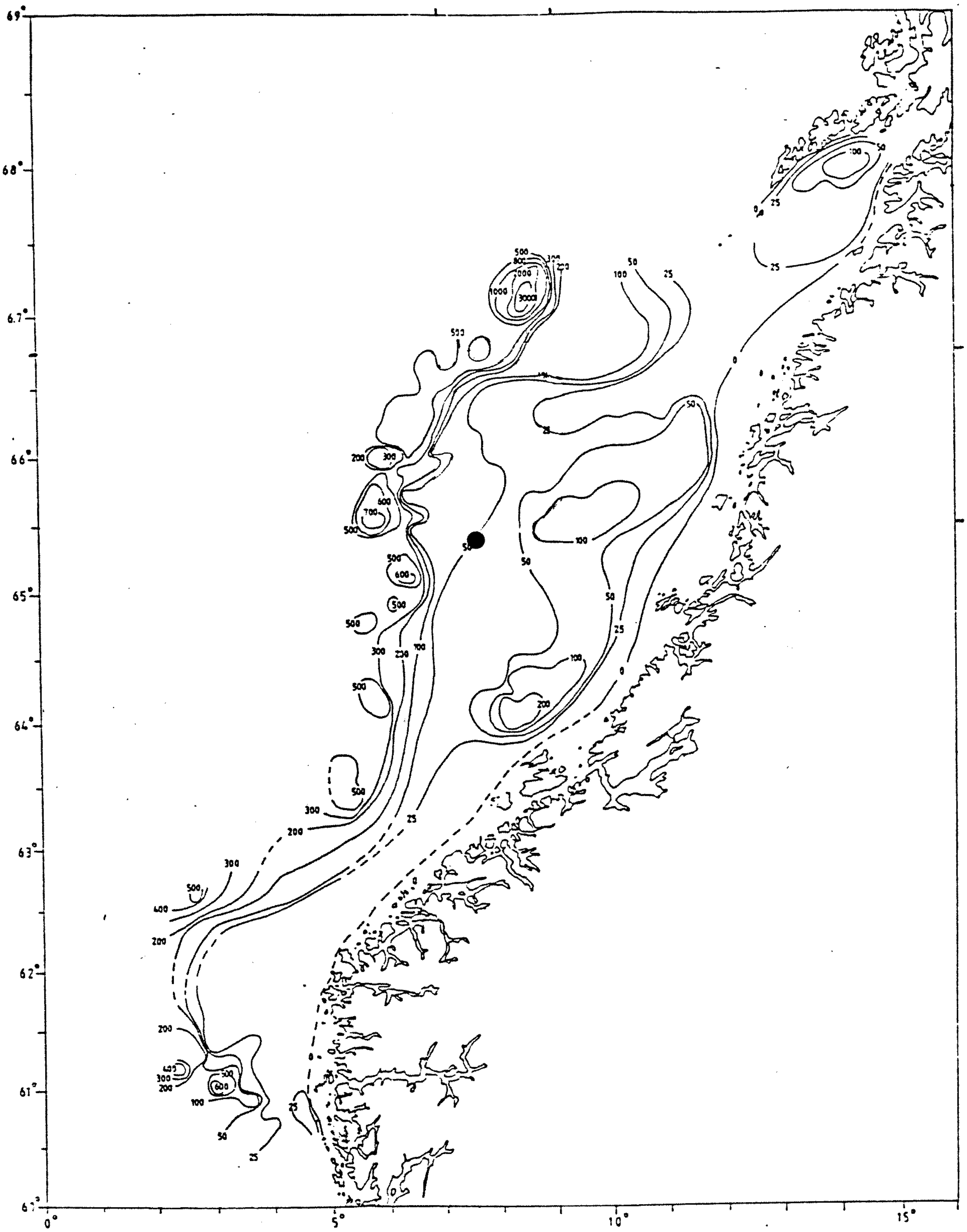


Fig. 3.3.1. Total amount of fish on the Norwegian continental shelf in spring 1985. The contour values are based on eccointegration. (Modified from Fiskerisjefen i Trøndelag 1985). Filled circle = Heidrun field.

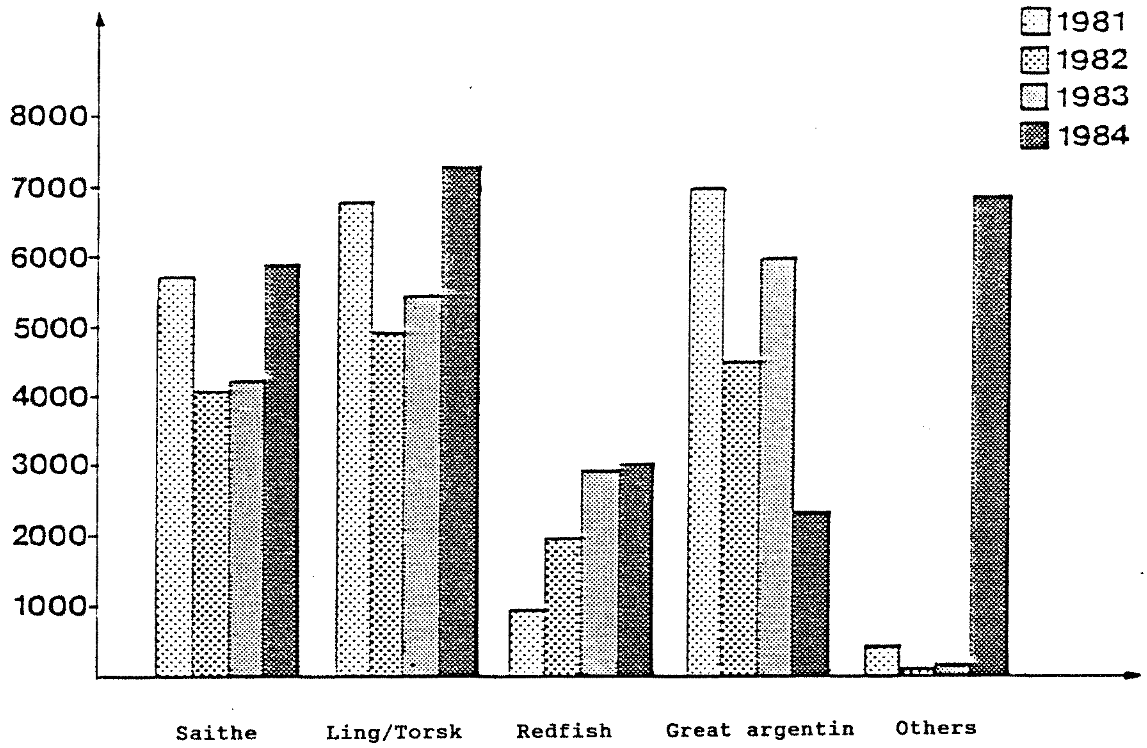


Fig. 3.3.2. Landings of fish (1000 kg/year) from the Haltenbanken area (06-hav). Others are mainly mackerel. (Modified from Fiskerisjefen i Trøndelag 1987).

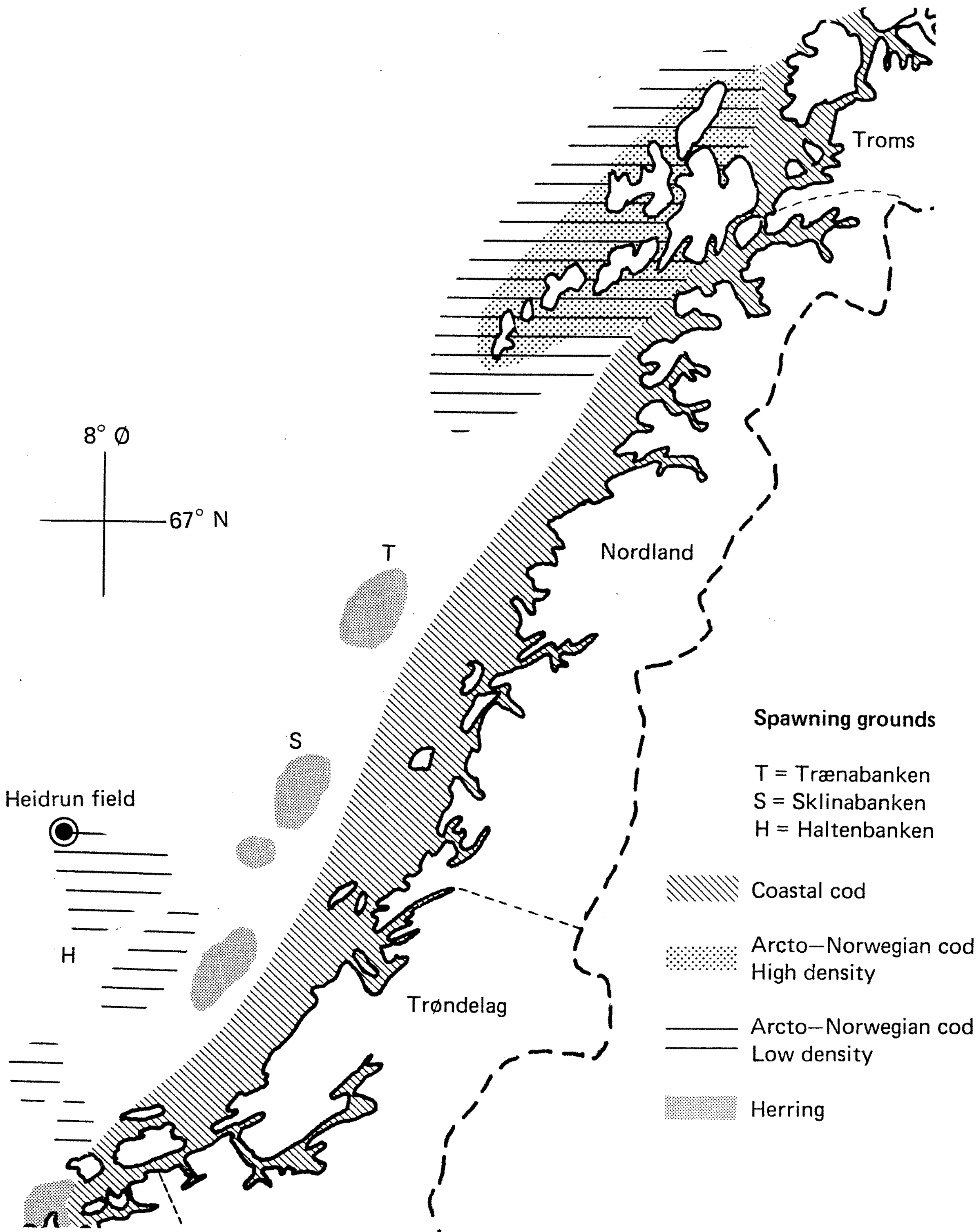


Fig. 3.3.3. Spawning grounds for important species. (Modified from St. meld. nr. 64, 1981-82).

water column which potentially affects the different life stages. These considerations cause the determination of the potential overlap between ecologically significant concentrations of hydrocarbons and the different life stages of fish to be uncertain. Especially a better data base for the spatial and temporal distribution of eggs and larvae would allow better predictions of effects on fish. The HELP (Havforskningens Egg og Larve Program) program in progress at Institute of Marine Research in Bergen will improve our knowledge on the spatial distribution of early life stages of fish along the Norwegian coast. This program was initiated in order to enable more realistic environmental impact assessments for fish resources in the future.

3.3.2. Concentrations of hydrocarbons found offshore after an oil spill

After an offshore oil spill the distribution of significant amounts of hydrocarbons is confined to the surface water masses with hydrocarbons confined to the volume of water above the pycnocline where the depth interval from 0-10 contains the major part of the petroleum hydrocarbons. Investigations after oil spills have, however, shown that oil may enter deeper waters and seafloor sediment, adsorbed on detrital material or incorporated in faecal material by sedimentation (Wade and Quinn 1980, Boehm et al., 1982).

After an experimental oil spill with Statfjord crude oil (100 t) on Haltenbanken (65^0,01'N, 7^0,30'Ø) in 1982, concentrations ranging from 20-80 ppb and 2-60 ppb were found at 1 and 9 m depth respectively during the first week of the spill (Jensen, 1984) in calm weather in July. Under more rough conditions the concentrations would probably have been higher caused by dispersion of oil droplets into the water column. Because of the relatively low solubility of hydrocarbons in water the maximum concentration of hydrocarbons in solution in water under floating fresh crude oil is not expected to be more than approximately 10 ppm (Reiersen and Berge, 1985). If dispersed oil is included this figure might be higher. However, after 5-15 days depuration (mainly by evaporation) from the crude oil will deplete the soluble components to a degree that the oil will no longer cause soluble components entering the water column. The oil would at this stage be practically non-toxic to fish.

The maximum concentration found in water after the "Argo Merchant", "Bravo" and "Amoco Cadiz" were 250, 400 and 22-340 ppb respectively

(Fiskeridirektorates Havforskningsinstitutt).

Contamination of fish has been found after several oil spills. Usually only very small amounts are found or only a small portion of the fish examined is affected. One week after the Ekofisk "Bravo" blow out fish (place, haddock, gurnard, long rough dab) caught within the slick area showed no evidence of a hydrocarbon contribution from the blow out (Law, 1978).

3.3.3. Biological effects

Avoidance

Fish resources within an area is determined by recruitment, mortality (natural and fisheries) and the balance of migration in and out of the area. Adult mortality caused by offshore avctivities is less likely than for eggs and larval stages since adult fish can move out of suboptimal water masses unless they are trapped in their habitat. This is not likely to occur off-shore. Adult fish are more independant of ocean and coastal currents than eggs and larvae which have no or limited possibility for horisontal migration. Adults have thus the potential of avoiding unfavourable water masses.

A prerequisit for such behaviour is that the sensory apparatus of the fish is capable of detecting such conditions and can get sufficient directional information out of the stimulus to detect the gradient inorder to let fish swim in the appropriate direction. The third condition is that the fish are equipped with behavioural responses which actually initiate the fish to move to more favourable water masses. Such behaviour is based on the assumption that the stimulus is meaningful for the fish. Experimental studies have shown that cod possess the ability to avoid concentrations higher than 50 ppb (Bøhle, 1983) and have sensory mechanisms capable of detecting concentrations near 1 ppb (Hellstrøm and Døving, 1983). The probability of adult mortality is also reduced since large animals usually move faster than smaller ones and the tissue of small organisms is more available to transport of toxic substances than larger ones because of unfavourable surface/volume ratios.

Migration

There has been many speculations on the effect of antropogenic substances on migration guided by pheromones. Pheromons have been demonstrated important for migration of salmonids in river and nearshore areas (Stabell, 1984). No conclusive evidence for interference with migration by petroleum hydrocarbons has been documented for offshore situations. Knowledge in this field is scarce (Stabell, 1980). With the present state of knowledge and experience no field evidence for offshore activities interferring with major migratory routes of fish has been documented.

Tainting

Tainting is caused by volatile components eleciting an olfactory response leading to the appearance of an "off flavor" taste of the fish. Oil contains a wide variety of different volatile components and the olfactory response to these is influenced primarily by (1) concentration and (2) strength of the flavour and aroma. Tainting is due to a complex mixture of substances of oil where minor components, principally sulfur and oxygen-containing and aromatic hydrocarbons are major contributors. Fish tainting can also be caused by nonpetroleum compounds of natural origin (See Connell and Miller, 1981 with references for review of tainting). The gills, intestine and integument are the most likely surfaces for transport of tainting compounds to the tissuer of adult fish.

The amount of lipid present in fish has been suggested indicative of susceptibility to tainting as body tissue with a high fat content is expected to absorb a higher concentration of hydrocarbons than fish with less lipid, implementing that herring, mackerell and salmon are more susceptible than cod, saith and haddock. The presence of detergents may also increase the uptake of petroleum products and must be considered if dispersants are to be used. The acquisition of taint can be rapid, in most cases occuring within 24 hours at concentrations comparable to those found under oil slicks.

After the blow out of the Bravo platform in the North sea in 1977 fish in the vicinity of oilslicks analysed for petroleum hydrocarbons showed no evidence of a contribution from the blow out (Law, 1978). However, haddock caught within 100 m from the Odin platform had elevated levels of aromatic hydrocarbons compared to fish caught in a pristine location (Vogt et al., 1985). Tainting effects, however, where not tested. Tainting of local populations attracted to the installation by the physical presence of the installations (artificial reef effect) can, thus, not be excluded. Experimental research have also documented that fish may take up hydrocarbons from contaminated sediment (McCain et al. 1978). This can be significant for bottom feeding fish in areas with discharge of drill-cuttings and in inshore areas after an oilspill. After the "Torrey Canyon" oil spill tainting was documented for mackerel (Scomber scombrus), sea trout (Salmo trutta) and flatfish, this was, however, suggested to be due to use of detergents in clean-up operations. In the case of a blow out there is, however, little evidence for tainting (Tidmarsh and Ackeman, 1986).

Experimental results from elimination of phenanthrene in rainbow trout (Salmo gairdneri) (Solbakken and Palmork, 1980) indicate that tainting compounds will be eliminated within one month for bony fish if the source of contamination is eliminated. Tainting caused by petroleum hydrocarbons is probably in most cases reversible and is not likely to affect a significant part of fish stocks off-shore for extensive time periods.

Pathological effects on adults

Adult fish can be killed by oil spills, this probably poses less of a threat to commercial fisheries than does damage to eggs and larvae (Teal and Howarth, 1984)

Pathological effects on adult fish are mainly confined to coastal and inshore areas where petroleum hydrocarbons may persist in sediments for years after a spill. A detailed review of pathological effects of hydrocarbons is not within the scope of this report. It is, however, important to note that fish are equipped with detoxifying system (MFO-system) for hydrocarbons (see Spies et al. 1982 with references). Within limits fish can eliminate xenobiotics encountered in the environment. Pathological effects on adult fish offshore are thus judged to be insignificant.

Effects of oil on adult fish are, however, documented for flatfish after the "Amoco Cadiz" spill. In estuaries heavily affected by the oil, macroscopic effects like fin and tail necroses were seen in flatfish and also several histopathological and reproductive disturbances (Haensly et al., 1982, Brule, 1987). The "Amoco Cadiz" grounded on the coast resulting in relativly unweathered oil reaching shallow water areas and being incorporated in the sediment and be a source to affect adult fish inhabiting sedimentary habitats. An oil-spill in the Heidrun field based on oil spill modelling (Chapter 4) wouldtake 5-10 days before it reaches the coast. Thus effects on adult flatfish would probably be more limited both because oil would be more weathered and because intertidally sedimentary habitats are more scarce than on the continent (see chapter 5).

Effects on eggs and larva

Eggs are more susceptible than adults (Teal and Howarth, 1984) and the probability of discharges and the distribution of hydrocarbons in the water masses after an oil spill are most likely to be confined near the surface. It can be concluded that species spawning in the area with pelagic eggs or larvae confined to the upper water masses are most vulnerable. Some key data for different life stages of fish found in the Haltenbanken area and other areas potentially effected by the Heidrun fieled development are presented in table 3.3.1 and 3.3.2. Species with early life stages found in the surface water are herring, saithe, haddock and cod (Table 3.3.2). Generally more than 75% of the total amount of fish larvae are found in the 0 - 15 m depth interval.

Table 3.3.1. Behavioural data for adult fish species important for the fisheries in the Heidrun area. P=pelagic, D=demersal, MP=mesopelagic. Main source: P. Pethon (1985)

Species	Adult behaviour	Main depth of adult (m)	Age when mature (years)	Maximum life span (years)
Herring	P	0-200	3-9	25
Saithe	P/D	0-200	5-6	27
Cod*	P/D	0-600	7-15	40
Haddock	D	40-300	3-4	20
Red-fish	MP	100-500	10-14	60
Great argentin	P	200-600	4-12	>20
Torsk	D	200-500	6-8	40
Ling	D	300-400	6-8	25
Round head rat-tail	D	100-1200		

* Arcto-norwegian cod

Table 3.3.2. Spawning data for fish species important for the fisheries on Haltenbanken. B=benthic eggs, P=pelagic eggs. Main source:P. Pethon (1985).

Species	Spawning time	Spawning depth (m)	Type of eggs	Distribution of eggs/larva (m)
Herring	Feb-Apr	10-250	B	0-40
Saithe	Jan-Apr	100-200	P	0-40
Cod*	Mar-Apr	50-200	P	0-40
Haddock	Mar-Jun	100-150	P	10-40
Red-fish	Apr-Jun	200-400?	P	10-160
Great argentin	May-Sep	300-500	P	400-500?
Torsk	Apr-Aug	200-400	P	?
Ling	Apr-Jun	100-300	P	200
Round head rat-tail	Oct-Feb	?	P	500-600

* Arcto-norwegian cod

The effects of hydrocarbons on eggs and larvae have mainly been studied through laboratory experiments both with individual components and with water soluble fraction of crude oil. In the Heidrun field context experiments with crude oil are relevant and studies with individual components are not considered because of problems with relating the results to field conditions. Of the species found in the Haltenbanken area mainly cod larvae have been tested extensively for toxic effects of crude oil.

The effects of hydrocarbons on fish larvae may be of physiological, biochemical, anatomic or behavioural nature. Effects of water soluble fraction of crude oil on cod eggs and larvae have been investigated and results have been compiled by Fyhn, 1986. The most significant detrimental results from these experiments were the reduction in oxygen consumption during the yolk-sac stage and 4 days after the yolk-sac where absorbed. This effect was found at exposure levels of 50 ppb, however, the threshold for this effect was not established. An implication of these results is that oil exposure of <50 ppb of water soluble fraction of crude oil effect energy production necessary for swimming and thus imped feeding activity. When the nutritional supply in the yolk-sac is exhausted, the survival of the larva is dependant on exogenous food. Oil exposure at levels of 50 ppb may, thus, seriously effects larval survival (Fyhn and Tilseth, 1986, see also Serigstad, 1986). Significant length reduction but no reduction in body dry weight has been documented in fish exposed to levels above 50-60 ppm of WSF for 2-6 days. No effects were found on osmoregulatory mechanisms or levels of free aminoacids in eggs and larvae (Fyhn and Tilseth, 1986). Morphological malformation in the foremost part of the head and jaw of early larval stages of cod has been documented after exposure to 50 ppb WSF of Ekofisk crude oil for two weeks (Tilset et al., 1984). The malformation resulted in reduced ability to capture prey organisms.

Thus concentrations found to be detrimental to larvae are in the same range as were found in an experimental oil-spill situation in relatively calm weather in July. But they are somewhat lower than maximum concentrations found in the water masses after some other oil spills (Argo Merchant, Bravo, Amoco Cadiz).

It is important to note that detrimental effects on juvenile stages do not affect fisheries before these individuals would have reached the age where they are harvested. Furthermore, increased mortality on eggs and larvae will not affect future spawning potential before the affected yearclass have reached maturity. The time needed for this varies from species to species (Table 3.3.1).

3.3.4. Important species - Potential effects of the Heidrun field development;

Herring (*Clupea harengus*)

The population of the spring spawning population of the Norwegian herring was reduced from 9 mill. to less than 0.1 mill. tons during the period 1956-1960 and remained at this low level for more than a decade. Present population estimates, however, indicates that the population has increased from 1972 to 1985, and that the 1983, 1984 and 1985 yearclasses are strong. The population is still small and can not support fishing of more than 150000 tonns in 1987 (Hamre and Røttingen, 1987). The prospects for the future herring fisheries is not as promising as only a few years ago. This is probably caused by desimation of young herring by an increased population of cod.

The migration of the Norwegian herring has changed significantly since the 1950's and it is impossible to predict the future distribution of this species along the Norwegian coast. The spawning grounds of herring is along the coast from Stadt to Lofoten (Fig. 3.3.3) in areas where the substrate consists of rock, gravel or shell sand. The most important spawning area is, however, between 62 and 65^0 N. One of three main spawning areas is in the Haltenbanken area southeast of the Heidrun field (Fig. 3.3). The herring spawn in February to April with the maximum intensity in spawning in the first part of March. Spawning takes place near the bottom at a total water depth of 40-250 m (max intensity 70-150 m) depending on the hydrographical situation in the area. After spawning the eggs sink to the bottom and adhers to the substrate. The eggs hatch after three weeks and the larvae start drifting with the coastal current predominantly northwards. The depth distribution of herring larvae in 1985 was between 0 and 100 m with a maximum in the depth range 40-60 m. Young larvae tended to be located nearer the surface than older and higher up in the water column during day time than during the night (Bjørke et al., 1986).

The spawning grounds of the herring are located at more shallower depths than in the Heidrun field. The effect of an oilspill on the surface would thus be a function of the amount and toxicity of the components which might come in contact with eggs and larvae.

Little or no effect on eggs will occur on the bottom since the volatile fraction of the oil reaching the subtidal will be undetectable and the amount of more heavy components limited. However, if drill cuttings or drilling mud were deposited in the spawning grounds this would seriously affect eggs present and would also reduce the quality of the area as a future spawning ground. Deposition of mud and cuttings should thus be avoided in such areas. In the Heidrun field area the water is to deep and the sediment relatively soft and, thus, not suitable for herring spawning. Thus the discharge of drill cuttings in the area would be insignificant on herring eggs unless the depth of the water column (350 m) through which the cuttings are transported leads to a wider distribution of cuttings and drilling-mud than in the North Sea.

The mean and minimal drift time for an oil spill in the Heidrun field at maximum spawning intensity (March) to the spawning grounds on Trænabanken are 15 and 5 days respectively. Sklinabanken and Haltenbanken 10-15 and <5 days respectivly and for the area outside Møre and Romsdal more than 15 days both for mean and minimal drift time. This means that larvae originating from spawning on Trænabanken are not likely to come in contact with water masses containing ecologically significant amounts of soluble hydrocarbons and are not likely to be affected by a possible oil spill in the Heidrun field. For larvae originating from Sklinabanken and Haltenbanken the worst possible conditions (Minimum drift time) can result in conditions which may cause effects on herring larvae. However, if mean conditions (mean drift time) are considered no significant effect is expected. Larvae from the coast outside Møre and Romsdal will only under the worst possible conditions have a possibility of coming in contact with water masses containing soluble components as the larvae drift past the Haltenbanken region.

The maximum density of herring larvae is found at 40-60 m depth and the largest concentration of soluble components under an oil-slick is found at 0-20 m depth under relatively calm conditions. The water mass offshore are relativly unstable im March (See Ray, 1981) and oil will probably be transported to deeper parts under more rough conditions. Thus under the worst possible conditions a significant part of the larvae within the slick area may be affected.

Saithe (Pollachius virens)

This species spawns in January to April at 100-200 m depth (35 o/oo, 6-10^{0} C) from Lofoten and southward along the Norwegian coast. An important spawning ground is in the Haltenbanken area. Saithe is usually confined to coastal areas and is seldom found at depths exceeding 200 m. Haltenbanken is an important fishing ground for saithe. During the period 1981-1984 the landing of fish from the Haltnbanken area has been 500 t per year, 60% of this has been caught by trawl. Fisheries on mature individuals (Storsei) on the spawning grounds are usually performed in January-March. A commercial fishery on younger year classes is also important. This fishery is diffusely distributed and a significant portion of the catches originates from the North sea population.

Saithe is a demersal species, however it is easily attracted by artificial structures. This behaviour may attract this species to offshore structures.

Arcto-Norwegian cod (Gadus morhua)

Mature cod arrives the spawning grounds in January to February and spawning takes place in March to April. The spawning grounds stretch from Finnmark to Stadt. The two most important spawning grounds are, however, in Vestfjorden, outside the coast of Møre and Romsdal and in Haltenbanken areas (Fig. 3.3.3). The cod spawns pelagically and the eggs float to the surface. The eggs hatch after 2-3 weeks. After the yolk sac is consumed the diet for the cod larva is mainly copepods (Calanus). Both eggs and larvae are transported by the coastal current predominantly northwards and reach the Barents Sea the following autumn where they turn demersal and grow up until 3-4 years old when they start a feeding migration to Finnmark during the winter and spring. After 7-10 years the cod becomes mature and starts a yearly counter current migration to the spawning grounds.

Because cod eggs and larvae are confined to the surface water masses and because concentrations found in the water after an oil spill may be above the threshold for serious sublethal effects on larval stages, an oil spill in the spawning season (March-April) could potentially have extensive effects on eggs and larvae under worst possible conditios for areas where oil less than 5-10 days old overlap with the distribution of eggs and larvae. The potential effect of this on future fish stock and fisheries is impossible to quantify whith present available database.

The mean drift time for an oil spill in the Heidrun field to the spawning grounds in Lofoten and outside Møre and Romsdal during the spawning season is 20 days (Fig. 3.3.3) and to the most important spawning grounds in the Haltenbanken area from 5 to 10-15 days. This implies that eggs and larvae originating from spawning in the Lofoten area will not be significantly affected by an oil spill in the Heidrun field, because oil will not result in significant concentrations of toxic components in the water column in the Lofoten area. For the component of the Arcto-Norwegian cod spawning outside Møre and Romsdal toxic concentrations are not likely to occur on the spawning ground (Fig. 3.3.3 see also chapter 4). However, since eggs and larvae are transported with the coastal current and predominantly parallel to the Norwegian coast the Møre and Romsdal component may be affected further north together with eggs and larvae originating from the Haltenbanken population if an oil spill occurs in the Heidrun field.

Since the spawning ground of the coastal population has a wide distribution and not so concentrated as the Arcto-Norwegian cod the effect of an oil spill would be only significant locally, if at all, and it would be the inshore fisheries that potentially would be affected.

Haddock (Melanogrammus aeglefinus)

The Arcto-Norwegian haddock has approximately the same distribution as the Arcto-Norwegian cod and is caught with the same equipment and in the same areas as the migratory cod. The haddock is a demersal species and feeds predominatly on benthic prey and prefers sandy or muddy sediment with some sand. Important spawning grounds are found in the Haltenbanken area. The haddock spawns in March-June at 100-150 m depth. The spawning grounds are more diffusely located than the migratory cod. The larvae are transported with the coastal current at 10-40 m depth. Present estimates of the population size are uncertain.

Since the spawning grounds of the haddock are diffusely located the effect of overlap between an oil spill and water masses containing eggs or larvae is less than would be expected for cod which perform a more concentrated spawning. On the other hand the probability for an overlap would be higher.The effect on eggs and larvae are expected to be simmilar to the effects on cod since they usually are found in the same water masses and have simmilar larval biology.

Red-fish (Sebastes marinus)

This species is distributed all along the Norwegian coast and is found partially on the continental slope 100-500 m and partially mesopelagic. Important spawning grounds are found in Vesterålen and Lofoten area.

Mature red-fish are distributed in deep waters and the eggs and larvae more shallow. This implies that mature fish are not likely to be affected by an oilspill.

Great argentin (Argentina silus)

This species lives pelagic from 100-900 m but is most common from 300-600 m. The mature part of the population is found in the deeper part of the depth range and the younger individuals mainly above 300 m. Spawning takes place in June-September and the eggs are pelagic at 400-500 m. The great argentin is distributed along the Norwegian coast from Skagerakk to East Finnmark. From 1975 a commercial fishery for this species started. Significant populations are found on the continental edge East of the Heidrun field (Johannessen and Monstad 1984). This species is one of the most important in the Trøndelag I and II area. Total landing from this area were 2300-7000 t per year during the period 1981-1984 (Fiskerisjefen i Trøndelag, 1987).

Because this species is pelagic and not confined to surface waters in any of its life stages it is expected that this species would not be effected by an oilspill at the surface. The effect of rupture of an subsurface pipeline from the Heidrun field would also be limited since such a pipeline would be located at depths above areas usually populated with the great argentin.

Ling (Molva molva)

This species is along the Norwegian coast most abundant between Stadt and Vesterålen and is most common at depths between 300-400 m. The ling is demersal and thrive in areas with boulders. This species spawns along the coast up to Vesterålen.

Because of depth distribution the ling is not expected to be significantly affected by offshore activity in the Heidrun field.

Basking shark (Cetorhinus maximus)

This species is found in the Haltenbanken area in spring and summer. It is at this time confined to surface water where it feeds as a filter-feeder. The basking shark is caught from small fishing vessels with a harpoon mainly in May. At present 500-700 are caught each year in Norway. Approximately 1/3 of this is caught in the Haltenbanken area (Fiskerisjefen i Trøndelag, 1987).

Since this species is a filter-feeder confined to surface waters it may potentially be exposed to oil in case of an oil spill. The effect of oil on filter feeding sharks is not known.

Round head rat-tail (Coryphaeonides rupestris)

Species living near the bottom in areas with soft sediment at depths from 100-1200 m where it mainly feeds on crustaceans. Significant populations of this species have been found both off-shore and in fjords in the Trøndelag area. The population in the Trøndelag area has been estimated to 15000 t (Eliassen, 1987).

This species will because of its depth distribution both as larva and adult not be effected by an oil spill. In areas with deposition of cuttings habitat disturbance would be expected. The effect of this on the population is judged to be insignificant.

3.3.5. Fisheries

Fishing gear

The main fishing gear used off the Norwegian coast in potentially affected areas is seen in Table 3.3.3. and Figures 3.3.4 - 3.3.6. Only long line are important in the vicinity (radius 4 n miles) of the Heidrun field platform with the most important area north of the platform (see Fiskerisjefen i Trøndelag, 1987). Loss of access due to the platform installation (1 km2) are however insignificant compared to the total fishing grounds.

Normal development and production activity probably also accidental oil spills are judged to result in undetectable effects on fish stock and landings of fish from the area (secondary effects of possible larval mortality are not included). Smothering of fishing gear confined to the surface by drifting oil is possible. Probably drift nets used for catching salmon in the zone between the "grunnlinjen" (refered to as base in figs. 3.3.4 - 3.3.6) and the 4 n mile territorial line in the period June to August would be most vulnerable. Supply ships are also a potential threat to these drift nets. This salmon fishery has been suggested prohibited from 1988.

Table 3.3.3. Types of fishing gear used offshore (outside "grunnlinjen") and species caught.

Gear	Main species caught
Long line	Torsk, ling, halibut, saithe
Trawl	Red fish, great argentine, saithe
Gill nets	Saithe
Hand line	Cod (Important in Lofoten area)
Seine	Saith
Harpoon	Minke whale, Basking shark
Drift nets	Salmon

Time of year

Landing of fish for different months from areas potentially affected by the Hiedrun field development and production is arranged in decreasing order of importance March, February, January and April (Table 3.3.4). This is also important months for spawning of fish with eggs and larvae confined to surface water (Table 3.3.2). Thus both for juvenile stages and adults, vulnerability is most pronounced in late winter and spring.

Table 3.3.4 Amount of fish caught (1000 kg)inside the 12 n mile zone throughout the year in four counties (From Fishery statistics 1984, Central Bureau of Statistics of Norway).

Month	Nordland	N-Trøndelag	S-Trøndelag	Møre og Romsdal	Total
Jan.	6911	490	291	7915	15607
Feb.	28946	879	401	7080	37306
Mar.	39652	1799	612	4131	46194
Apr.	10056	1150	911	1985	14102
May	3482	1025	645	1615	6767
June	2068	319	175	994	3556
July	1872	279	303	665	3119
Aug.	3397	763	549	2563	7272
Sept.	6021	716	1568	2953	11258
Oct.	10035	1620	796	5504	8955
Nov.	10047	704	433	4374	6558
Dec.	4997	306	234	1512	7049

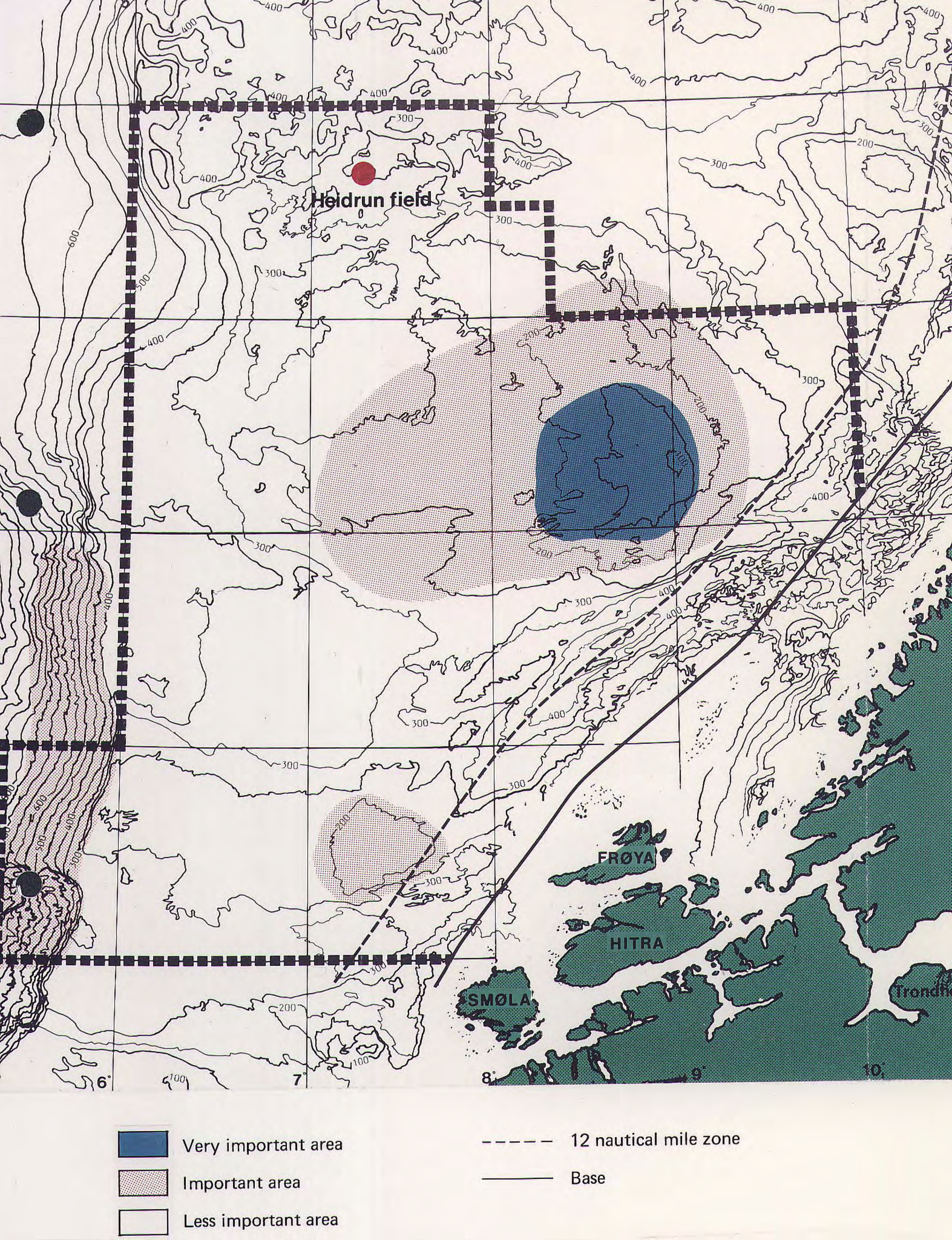


Fig. 3.3.4. Areas on Haltenbanken (Trøndelag I and II) used for fishing with nets. (Modified from Fiskerisjefen i Trøndelag, 1987).

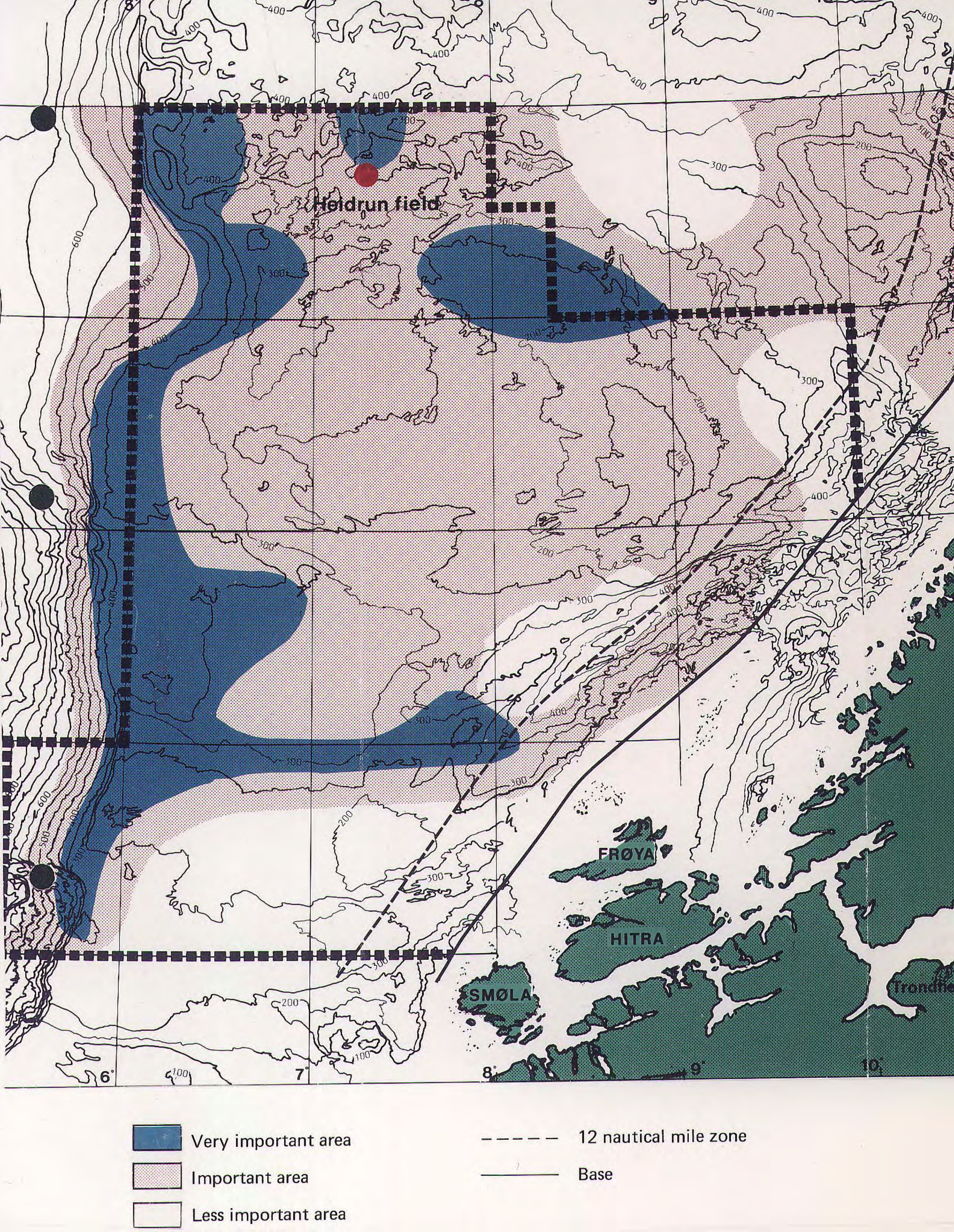


Fig. 3.3.5. Long-line grounds in the Haltenbanken area (Trøndelag I and II). (Modified from Fiskerisjefen i Trøndelag, 1987).

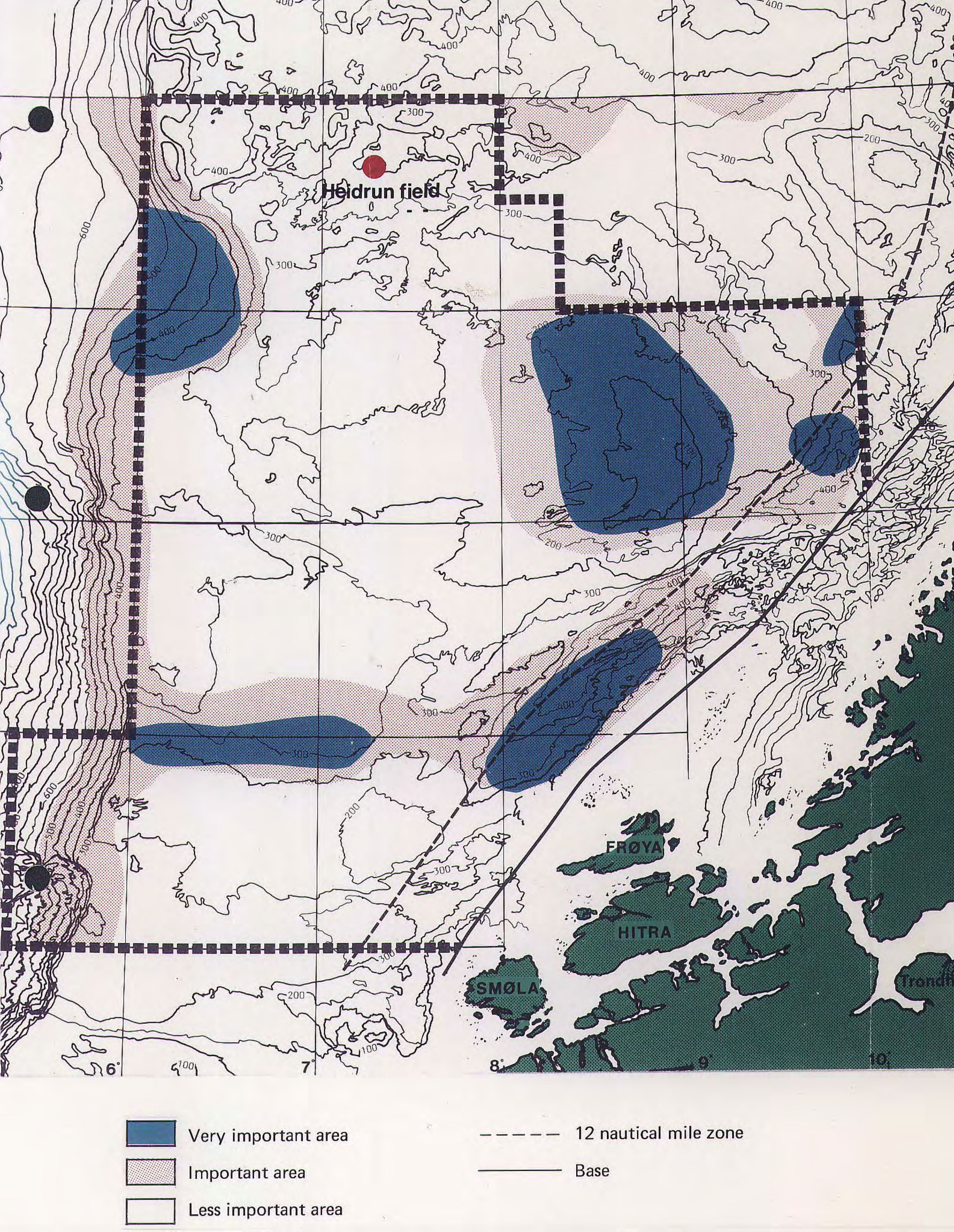


Fig. 3.3.6. Trawling grounds in the Haltenbanken area (Trøndelag I and II). (Modified from Fiskerisjefen i Trøndelag, 1987).

3.3.6. Conclusions

Haltenbanken is an especially important area of the continental shelf and contains spawning and nursery grounds for commercially important species. The landings of fish from the area are also significant. Important species in the area are: cod, saithe, haddock, herring, place, redfish, ling, torsk and great argentin. Several of these specis perform countercurrent spawning migration to the Haltenbanken area in order to compensate for the drift of eggs, larvae and juveniles.

The distribution of the different life stages of individual species is to a large extent determined by prevailing hydrographic conditions. For a specific future point in time the distribution of fish can not be estimated accurately. The HELP program performed at Institute for Marine Research in Bergen will improve our present knowledge on spatial and temporal distribution of early life stages of fish on the continental shelf and will enable more realistic environmental assessments in the future.

After an oil spill the distribution of significant amounts of petroleum hydrocarbons is confined to the surface water masses (down to the pycnocline) where the depth interval from 0-10 m contains the highest concentrations. After an experimental oilspill on Haltenbanken concentrations ranging from 2-80 ppb were found in this depth interval. The maximum concentrations found in seawater after several oil spills are 400 ppb.

Contamination of fish has been found after oil spills. Usually only small amounts are found and only a small portion of the fish examined is affected offshore. One week after the "Bravo" blow out fish caught within the slick area showed no evidence of contamination. However, fish caught within 100 m from the Odin platform showed elevated concentrations of aromatics during normal operational activities.

Adult mortality caused by contamination from offshore activities is less likely than effects on early life stages because adults may move out of suboptimal water masses.

Tainting is a potential effect on fish offshore in case of an oil spill in the Heidrun field, but will not affect significant parts of fish stocks. The acqusation of taint may occur within 24 hours at concentrations comparable to those found under an oil slick. Tainting is a reversible effect which will be eliminated within 1 month after exposure has stopped.

Whithin limits fish can eliminate xenobiotics encountered in the environment through a detoxification system (MFO-system). Pathological effects on adults will probably not be significant off-shore, but are documented in coastal and inshore areas when fresh oil is trapped in intertidal sediment.

Eggs and larvae are more susceptible than adults. Documented effects on eggs and larvae are found at concentrations near 50 ppb. Since the highest concentrations are found near the surface, species with eggs and larvae in or near the surface (herring, saith, haddock and cod) are more suceptible than species with the young lifestages in deeper waters (Red-fish, great-argentin, Round head rat-tail). Benthic eggs (herring) are only affected in areas where drill cuttings and associated mud is deposited. The concentrations found to be detimental to larvae are in the same range or lower than concentrations found after an oil spill.

Important areas for herring spawning are, however, not found in the area potentially affected by discharge of cuttings (radius 5 km from source of discharge) on the Heidrun field.

Harmfull effects on a yearclass of eggs and larvae do not affect fisheries before individuals which have died would have reached the age when harvested and will not affect future spawning potential before they would have reached maturity. Density dependant survival mechanisms may, however, to some extent compensate fore harmful effects.

Larvae originating from spawning on Trænabanken and in Lofoten are not likely to be affected by the planned activity in the Heidrun field. However, larvae originating from spawning south of the Haltenbanken may be affected further north together with larvae originating from Haltenbanken if an oil spill occurs in the Heidrun field.

Long line is the most important fishing gear used in the vicinity of the Heidrun field. Loss of access due to the platform installation is insignificant compared to the total fishing grounds. Normal development and production activity and probably also oil an oil spill are judged to have undetectable effects on fish stock and landing of fish from the area. Supply ships and smothering of fishing gear in case of an oil spill, are a potential threat especially to drift nets for salmon.

Both for juvenile stages and for adults the most vulnerable period is in late winter and spring.

3.4.PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SEDIMENTS OFFSHORE

3.4.1 Objectives

The primary objectives of the environmental assessment of the bottom sediments of the Heidrun Oil Field are:

(i) to consider the existing knowledge of the physio-chemical properties of the surface sediments (0-10cm)

(ii) to evaluate the applicability of these data as an environmental baseline for the development of the Heidrun field, and

(iii) to foresee potential environmental impact on the sediments at the site of production.

3.4.2 Sources of information

The primary source of information for this chapter is "Haltenbanken baseline survey. Physical, chemical and biological characteristics of the surface sediments" (Bowler *et al.*,1985).

A total of 38 sediment stations were sampled in a grid formate covering 19 concession blocks (Fig. 3.4.1). The sampling survey was carried out in May 1985, at which time a total of 22 exploration wells had been drilled or were in progress in the survey area. Sampling sites were located at last 3 km from existing well-sites, and potential effects on the physical and chemical charachteristics of the sampled sediments due to drilling operations were considered to be minimal.

(Main bathymetry contours: ——200 m, - - - 300 m, ······· 400m).

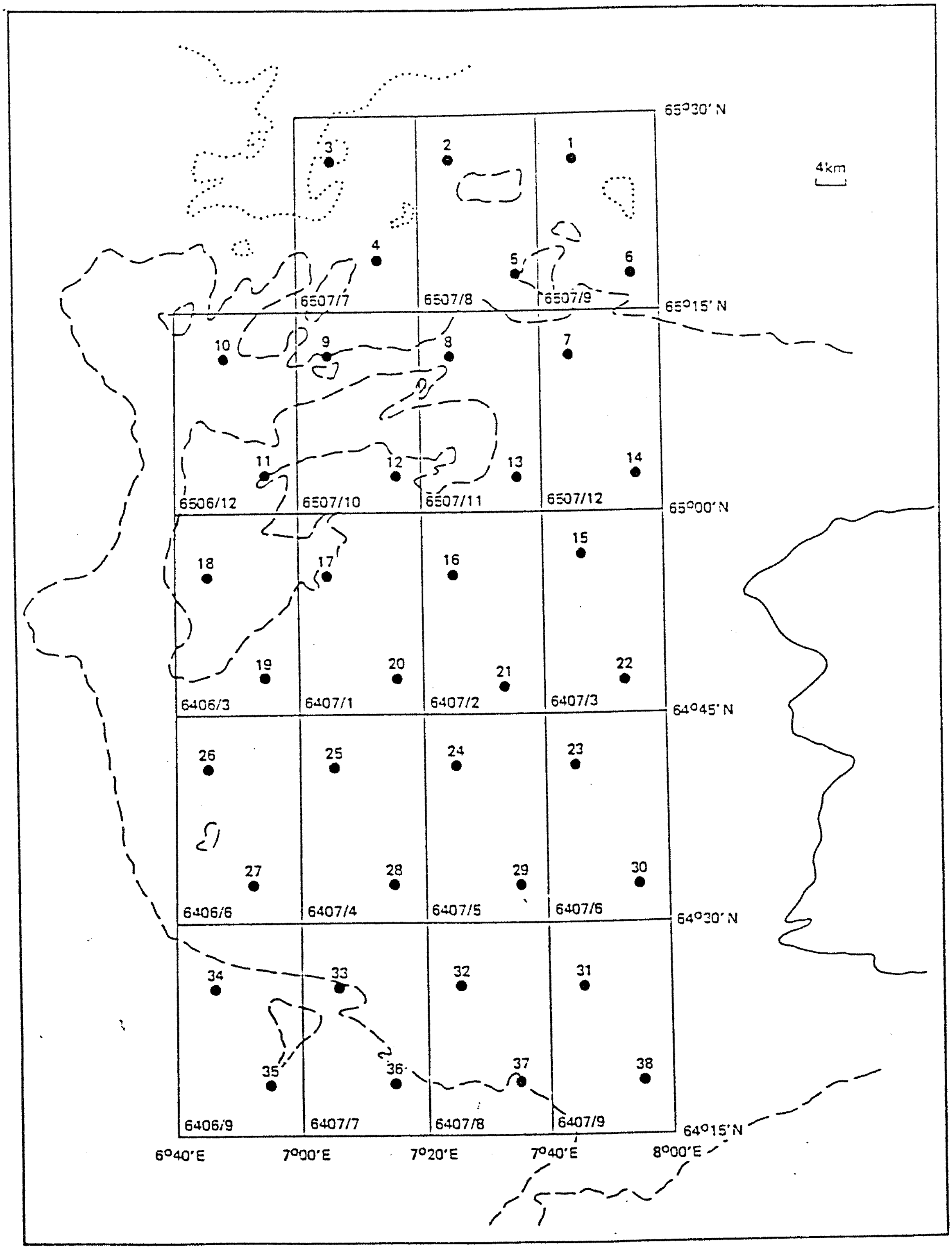


Figure 3.4.1 Sampling stations at Haltenbanken, May 1985 (after Bowler et al.,1985).

The characterisation of the surface sediments involved measurement of the following parameters:

1. Visible features of the sediment surface, including photographic documentation

2. Oxidation-reduction (redox) potential (Eh) and pH.

3. Grain-size distribution.

4. Content of the metals calcium, aluminium, iron, magnesium, barium, chromium, nickel, vanadium, zinc and copper.

5. Total carbon content and total organic carbon content.

6. Content of extractable organic material.

7. Total hydrocarbon content (aliphatic + aromatic hydrocarbons).

8. Sterane and triterpane distributions (semi-quantitative analysis).

9. Content of naphthalene, phenanthrene, dibenzothiophene and the alkylated derivatives of these compunds.

Other sources of information are reports on sediment charachteristics at other oil fields in the North Sea and published papers in the open literature (see reference list).

3.4.3. Physical charachteristics

The physical properties included are:

(i) visual description of the sediments (colour, odour, texture)

(ii) grain-size distribution, including parameters like mean particle diameter, sorting and skewness

(iii) Eh and pH measurements.

From the sampling grid shown in Fig. 3.4.1 stations from 1 - 10 are considered the most relevant for the Heidrun field. They will describe the sediments in the northernmost part of Haltenbanken, including block 6507/7 and the Heidrun field. Station 4 (Fig. 3.4.1) is located inside the approximate limits of the oil/gas reservoir of the Heidrun field. The topography of the northern Haltenbanken region is very irregular with water depths varying between 300 and 400 m (Station 1 - 10, depth range: 260m - 390m).

The sediments have been visually described as sandy silt and silty sand, some of them clayey and with a certain gravel content.
At station 4 (Heidrun field) the surface sediments were described as sandy silt (clayey), overlying silty stiff clay. The sediments of the northern part of Haltenbanken (Station 1 - 10) contain less pebbles and gravel than in the southern part. Their visual appearance indicates that they originate from drift or till deposition under glacimarine conditions and have subsequently been reworked to varying degree.

The surface sediments of the north have a light brownish colour, presumably due to the presence of iron/manganese oxides. The surface sediment at station 4 was described as olive gray. No unusual odours were detected in any of the samples.

The very variable and irregular sea floor topography is reflected in the grain-size distribution. Some areas are predominately exposed to erosion and others to deposition. Due to these factors it is difficult to generalize and extrapolate. To what extent station 4 (Fig. 3.4.1) is representative with respect to grain size of sediments within the Heidrun field, is difficult to assess.

The water depth of the Heidrun field varies between 325 and 350m, suggesting that the local topography is rather uniform and hence the grain size of the sediments may be reasonably homogenous.

At station 4 the sediment is classified as medium silt with median diameter of 5.55 (Md_0) and a very poor sorting (std.dev. = 3.48). The sediment consists of 20.5% sand, 46.7% silt and 32.5% clay. The fineness of the sediment suggests that the area may be charactherized as a low-energy-area, where deposition preponderates erosion. The poor sorting, however, indicates that reworking of till material takes place.

Measurements of Eh and pH in the sediments of Haltenbanken area give some indications of the redox conditions. Determinations of Eh and pH were made at 2 and 8 cm depth in the sediments (surface sediments). An average of +503 mV at 2 cm and +162 mV at 8 cm for the whole indicates that the surface sediments in the survey area are well-oxygenated with aerobic conditons occurring to a depth of at least 8 cm below sediment surface. The station at the Heidrun field (station 4) showed Eh-values of +353 mV and + 175 mV at 2 and 8 cm respectively, indicating conditions similar to the average.

A slightly lower value at 2 cm depth at station 4 compared to other stations may reflect the fineness of the sediment and less exchange of oxygen across the sediment-water interface.

The pH values in the northern part of Haltenbanken is somewhat lower than in the south. At the Heidrun field a value of 6.90 at 2 cm and 6.87 at 8 cm was measured, which is quite low. This may reflect the mineralization of organic matter in the sediments and the grain size. It is stated that the Haltenbanken sediments may be anoxic below ca 10 cm from the sediment surface.

3.4.4. Chemical characteristics

The chemistry of the sediments of the Haltenbanken area is based on the following parameters:

(i) Content of the metals calcium, aluminium, iron, magnesium, barium, chromium, nickel, vanadium, zinc and copper.

(ii) Total carbon content and total organic carbon content

(iii) Content of extractable organic material

(iv) Total hydrocarbon content (aliphatic + aromatic hydrocarbons).

(v) Sterane and triterpane distributions (semi-quantitative analysis)

(vi) Content of naphthalene, phenanthrene, dibenzothiophene and the alkylated derivatives of these compounds.

The range of parameters is selected from the knowledge of the composition of waste material being produced during platform activities in an oil field. In the case of metals some of them are typical components of produced water (calcium, aluminium, iron and manganese). The source of elements like barium, chromium and nickel is to a large extent drilling fluid.

All the above mentioned substances (i - vi) have a natural content in marine sediments. This has to be taken into account when considering environmental impact.

The average content of metals in the surface sediments of the whole area, the northern part of Haltenbanken (Station 1-10) and the Heidrun field is shown in Table 3.4.1.

Table 3.4.1 Metals in surface sediments of Haltenbanken area (from Bowler *et al.*, 1986).

Parameter	Total average(%)	Average of station 1-10(%)	Station 4 (%)
Ca	6.96	7.38	8.23
Al	5.07	5.01	4.96
Fe	2.50	2.56	2.48
Mg	1.03	1.03	1.05
Ba	0.034	0.035	0.034
Zn	0.009	0.018	0.011
Ni	-	-	<0.002
V	0.006	0.006	0.006
Cr	-	-	<0.002
Cu	<0.002	-	0.001

From table 3.4.1 it is evident that the sediments in the northern part of Haltenbanken are very rich in calcium with a concentration of 8.23% at the Heidrun field. Analyses of 50 sediment samples (silt) from the Barents Sea (Wright, 1972) gave an average value of 1.29% calcium. The high calcium at Haltenbanken may be explained by the presence of calcium carbonate (shell fragments or a carbonate source rock), as a reasonably good correlation can be seen between calcium and inorganic carbon.

The other elements show small areal changes, except zinc which seems to appear at slightly higher concentrations to the north. The detection limits of copper, chromium and nickel given are too high to make data interpretation possible. It should also be pointed out that the analyses are performed on bulk samples (all grain-sizes). As the metal content in sediments is normally grain-size dependent, variations in concentrations in an area where grain-size is highly variable may be expected.

Analyses of total carbon and total organic carbon illustrate the organic loading on the sediments and the content of carbonates. Table 3.4.2 shows the levels measured at the Haltenbanken area.

Table 3.4.2 Total carbon (TC), total organic carbon (TOC) and inorganic carbon (TC-TOC) in the Haltenbanken sediments (after Bowler *et al.*,1986).

Parameter	Total average (%)	Average of station 1-10 (%)	Station 4 (%)
TC	2.22	2.30	2.58
TOC	0.40	0.35	0.38
TC-TOC	1.82	1.95	2.20

The results in table 3.4.2 indicate that the levels of inorganic carbon increase towards the north. This is in agreement with the calcium results, suggesting the presence of carbonate.

The content of extractable organic matter (extracted with dichlormethane) represents in addition to hydrocarbons other lipids including esters, alcohols, glycerides, ketones, resins and pigments. Extractable organic matter is therefore not necessarily only identical with oil or hydrocarbon content. The total range for the Haltenbanken survey was 4.0-27.7mg/kg DCM-extractable organic matter. The sediment of the Heidrun field contained 12.6mg/kg. The values are considered to be normal for unpolluted sediments.

Total hydrocarbon content of the sediments includes aliphatic and aromatic hydrocarbons which are the dominant components of fossil fuels and ancient sediments.
Oil based drilling fluids are comprised of approximately 85% aliphatic hydrocarbons, 4% aromatic hydrocarbons and 10% polar

components.

The aliphatic hydrocarbons comprised about 10% of the total at Haltenbanken. For comparison the sediment at Heidrun field (station 4) contained 12.8% aliphatic hydrocarbons. The corresponding values for aromatic hydrocarbons were 16.7% and 18.4%. It was concluded that the DCM-extractable organic material is comprised mainly of polar compounds indicating a recent (biogenic/natural)origin. There was no sign of any hydrocarbon pollution.

In addition to analyses of aliphatic and aromatic hydrocarbons, selected components (biomarkers) were also identified. These include bicyclic alkanes, steranes and triterpanes.
The analyses of these components revealed that the organic matter present in the surface sediments of Haltenbanken is predominantly of terrestrial source and of relatively recent origin. There was little evidence to indicate contamination of the sediments by fossil fuels. Based on these indicators or biomarkers the organic material may be characterized as intermediately mature.

The aromatic hydrocarbon fraction was separated using thin-layer chromatography and the contents of naphthalene, phenanthrene, dibenzothiophene and the alkylated derivates of these compounds (C_1-C_3 alkyl homologs) quantified. The contents of total naphthalenes, total phenanthrenes and total dibenzothiophenes at the majority of sampling stations at Haltenbanken were less than 15 µg/kg, 15 µg/kg and 4 µg/kg (dry weight) respectively. The sediments at the Heidrun field contained 6.3 µg/kg, 9.7 µg/kg and 1.6 µg/kg respectively. These values are consistant with those reported for unpolluted sediments from other areas of the North Sea and Norwegian Sea.

3.4.5. Evaluation of existing data as an environmental baseline

The charachterization of the sediments at the Heidrun field is based on a single survey performed at Haltenbanken in May 1985. The sampling grid covers 19 blocks (ca. 8 500 km^2), with 2 stations in each block. The distance between sampling stations ranges between 14 and 18 km, and the stations were located at least 3 km from existing well-sites. This implies that the sediment survey does not allow a detailed charachterization of the Heidrun sediments. On the other hand, the depth variations within the Heidrun field are relatively small and it may be assumed that station 4 in the SW part of the Heidrun field is relatively representative of the field as a whole.

During the Haltenbanken survey the sampling stations were located 3-4 km away from the nearest well-site. This implies that the possible influence of the drilling activities would be minimal or non-existent at the site of sediment sampling. Additionally, most of the drilling activity in the Heidrun field took place after the May 1985 sampling. Based on these conditions, the result from the May 1985 survey may be considered as a baseline for the area, representing almost pristine conditions.

The range of parameters charachterising the sediments is comprehensive and will serve as important background information for later surveys. The quality of the data appears generally to be good but the following comments should be made:

(i) Based on the photographs of the surface sediments it appears that loss of water above the sediment surface and drainage through the sediment was a problem. This may have washed the very top of the sediment away.

(ii) Reproducable numbers of Eh and pH in sediments is difficult to obtain. Therefore it will be difficult to use these parameters in trend monitoring as absolute numbers generally are quite unreliable.

(iii) The interpretion of chemical data in sediments is complicated when doing inter-station comparison. This is due to grain-size dependance, particularly for metals. If the analyses additionally were performed on one fraction (e.g. < 63 µm or silt/clay), comparisons and trend monitoring would be more meaningful.

(iv) The detection limits of copper, chromium and nickel are too high compared with background levels in marine sediments. Improved techniques should be preferred.

3.4.6. Potential environmental impact on the sediments of the Heidrun field during development and production.

Experience from other oilfields in the North Sea and elsewhere has shown that the impact on sediments surounding platforms may be summarized as follows:

(i) Extensive smothering of the seabed within a radius of 200-500 m from the platform.

(ii) Increase in the level of metals associated with drillmud and cuttings in the sediments surrounding the platform within a radius of 1-2 km (or more).

(iii) Increase in the level of hydrocarbons in the sediment in the imediate area around the platform if oil-based drillmud is used.

(iv) Change in the grain-size of the sediments around the platform as a result of deposition of drillmud and cuttings.

(v) Change in the redox conditions in the sediments near the platform due to hypersedimentation (including domestic sewage from platforms).

The extent of impact will depend on the following:

(i) Bottom currents at the platform site

(ii) Water depth

(iii) Type of cuttings used (water-based, mud/oil-based mud)

(iv) The amount of discharge

(v) The grain-size of the discharged solids.

If strong bottom currents prevail the solid waste will be wide spread and no hypersedimentation will take place. This implies small gradients of pollutants in the sediments, although the area of influence may be large. By increasing water depth the distance between the depth of discharge and the seabed will be larger. As a consequence the solid waste may be transported further away before depositing on the seabed.

Varies types of muds have been used in the North Sea, i.e. water-based muds, diesel-based mud and low-aromatic oil-based mud.. A review of the environmental effects of using oil-based drilling muds in the North Sea has been given by Davies et al., 1984.

A series of experiments, both in the field and in ecosystem enclosures were carried out by Norwegian Institute for Water Research (NIVA) during 1982-86 on the effect of varies drillmuds on sediments and biota (Bakke et al. 1985 a, b, c; 1986). Based on the existing experience it appears that the impact of cuttings on the sediments is limited to 2 000 - 3 000 m from the platform. Excessive impact may occur within 500 m from the platform, due to hypersedimentation. Fig. 3.4.2 shows the distribution of total oil in sediments with increasing distance from a number of platforms in the North Sea.

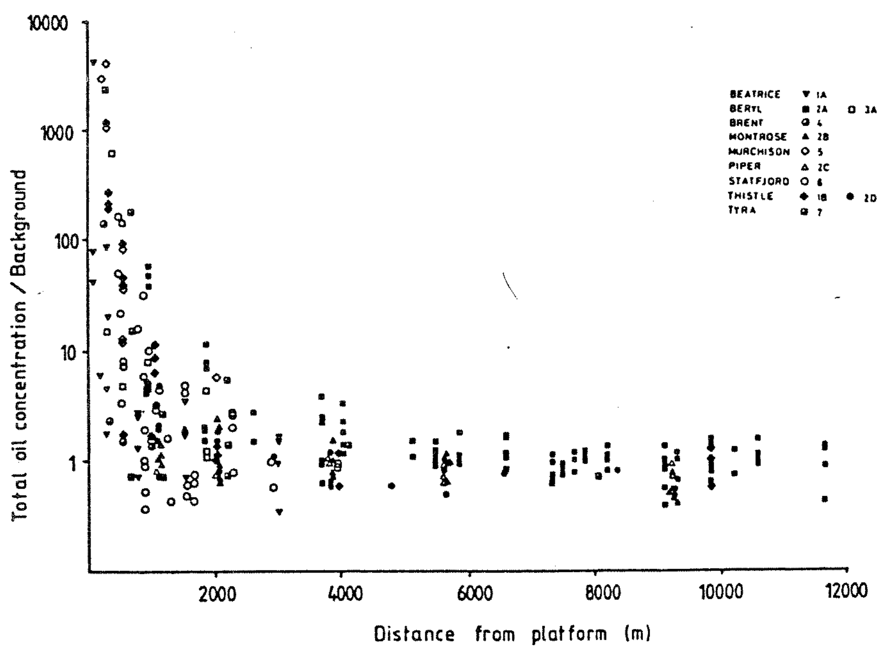


Fig. 3.4.2 The concentration of "total oil" related to the distance from a production platform (from Davies et al.,1984).

In additon to changes in the chemical composition of the sediments surrounding platforms it also occurs a change in the grain size of the sediment (Fig. 3.4.3).

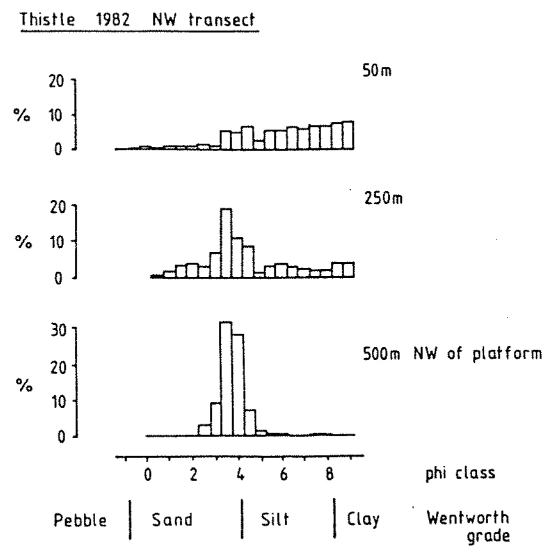


Fig. 3.4.3 Changes in particle size distribution of seabed sediment with distance from the Thistle platform (from Davies et al., 1984).

This is due to accumulation of fine mud particles and cuttings close to the platform.

Tests carried out by NIVA on oil-based cuttings indicated that deposition of cuttings on sediment surfaces caused a reduction of the redox potential (Bakke, 1985 a). Furthermore, an extensive flux of selected aromatic hydrocarbons (NPD) was observed from oil-based cuttings to the above-lying water, due to the relatively high water solubility of the NPD's (Bakke, 1985 a).

Environmental surveys at the Heimdal field (Bowler et al.,1986) indicated contaminations of the sediments by organic and inorganic compounds within 500 m from the platform. The sediments here consisted of moderately sorted, very fine sand, with a silt and clay content of 10-14%. Compared with the Heidrun field the sediments of the Heimdal field are considerably coarser. No major change in grain size occured during the two years of drilling (1984-86). An increase in the barium concentration, however, suggests that the sediments surrounding the platform were influenced by drilling mud (Bowler et al.,1986).

The Statfjord environmental survey of 1986 (A/S Miljøplan, 1987) clearly showed the effect of dischanges of oil-based drilling mud and cuttings on the sediments. Maximum metal concentrations occured close to the platforms, dropping to background levels at 1000 m distance. Barium showed elevated levels beyond 1000 m (Fig. 3.4.4.).

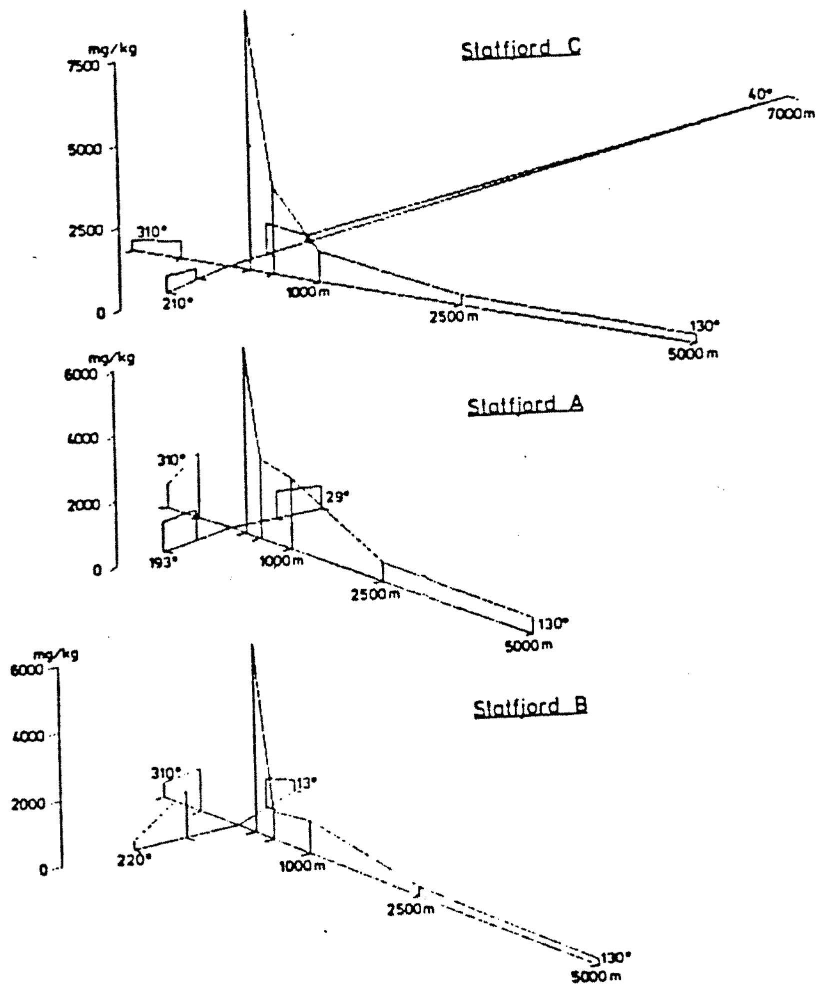


Fig. 3.4.4. Statfjord field July 1986. Distribution of barium in sediments.

The hydrocarbon content of the Statfjord sediments decreased sharply with distance from the platforms, with levels of 10 000 ppm close to platform (A/S Miljøplan, 1987). The 100 ppm and 1 000 ppm levels extend farther away from the platform at Statfjord A than at Statfjord B and C. This may be due to a nearly 5 times greater discharge of dissolved hydrocarbons at Statfjord A than the other two (A/S Miljøplan, op-cit). The sediments of Statfjord field may generally be charactherized as medium or coarse sand, and hence very different from the Heimdal field. The silt-clay content of Statfjord sediments consituted 0.4-4.6% compared to 79.2% at the Heidrun field. A slightly higher silt-clay content in sediments close to the platforms at Statfjord indicates the influence of drill muds and fine cuttings. The water depth at the Statfjord field is about 150 m compared to more than 300 m at the Heidrun field.

To make a prediction of the potential environmental impact on the sediments of the Heidrun field, as a result of drilling and production, experience from other oil fields and local conditions have to be considered. The other oilfields in the North Sea are mostly situated at much shallower water, with depths varying between 60 and 150 m. The water depth at the Heidrun field is 330 m. Also the grain size distribution is completely different between the shallow fields and Heidrun. A mud content (< 63 µm) of 0.5-2.0% is typical for many of the oil fields in the North Sea, while a corresponding mud content in the sediments of Haltenbanken is between 36 and 95%. The implication of a large water depth and fine-grained sediments is a different sedimention environment at the Heidrun field compared to most of the others. If we assume that mud and cuttings are discharged in the upper 50 m of the water column, the long distance to the sea floor will result in wide spread deposition of the solid discharge. This implies that the gradients of pollutant substances in the sediments away from the drilling site will be less steep, but the area of influence will be greater. The high mud content of the sediments at Heidrun suggests that fine-grained mud and cuttings may be accumulated in the sediments without beeing eroded away. The presence of gravel along with clays at some of the stations at Haltenbanken indicates till-deposits and very little post-glacial sedimentation. This may be due to lack of source material rather than erosion. By adding a man-made source of sediment the net sedimentation rate will increase and the pollutant substances will impress on the sediment quality.

The extent of impact on the sediments during development and production will depend on the following factors:

(i) The amount of solid waste discharged (mud, cuttings, sewage etc.)

(ii) The depth of discharge

(iii) The current regime at the site at varies depths

(iv) The grain-size of the solid waste

(v) The relative abundance of natural and man-made sedimenting particles

3.4.7. Summary

During a single sediment survey of the Haltenbanken in May 1985 (Bowler et al.,1985), the physio-chemical properties of the sediments of the Heidrun field (one station) were investigated. The results may be summarized as follows:

- the sediments consist of sandy silt (clayey) overlying silty stiff clay.
- the mud-content (< 63 µm) is more than 75%, which is very high compared to other oil fields.
- the sediments are oxygenated in the upper 10 cm. Slightly reduced Eh at 2 cm depth compared to other localities at Haltenbanken may indicate slow rate of oxygen diffusion into the sediments due to the high mud-content.
- the sediments are highly enriched in calcium presumably due to the presence of shell fragments ($CaCo_3$).
- the metal content of the sediments is normal, indicating a pristine area. Small changes in concentrations in the Haltenbanken area may be explained by grain size differences.
- more than 80% of total carbon in the sediments may be explained

by the presence of carbonate. The organic carbon content is low (approxemately 0.4 %).

- the levels of hydrocarbon components indicate unpolluted sediments.

The existing data provide valuable environmental background information. Due to very little drilling activity at the Heidrun field prior to the survey, the data may be used as a baseline. The amount of data from Heidrun field is very limitied (one station) but it may be rather representative due to a relativly homogenous bottom topography near the Heidrun field.

The potential impact on the bottom sediments on the Heidrun field due to drilling and production may be summarized as follows:

- hypersedimentation of cuttings and drillmud in the near vicinity of the platform. The area of influence will depend on the choice of discharge depth (discharge point close to the seabed will cause a small area of influence while increased distance from the sea bed will increase the area of influence).

- increased levels of specific metals (Ba, Fe, Cr, Ni, V) within a certain distance of the platform.

- increased levels of hydrocarbons in the sediments near the platform depending on the type of cuttings used (oil-based/water-based)

- reduced diffusion of oxygen into the sediments due to sedimentation of fine particulate matter. The ultimate result is decreased Eh and anoxic conditions, devoid of macroscopic life.

The high mud-content and the great water depth of the Heidrun field are charachteristics which are different from other fields. High mud-content indicates that discharge of fine particles from the platform may find their way to the sediments to become permanently buried. This will decrease the particle size of the sediments and anoxia may gradually develop and destroy the biota. The extent of redox influence will depend on the rate of sedimentation of contaminants, which again depends on the behaviour of the discharge plume.

3.5. BENTHIC AND EPIBENTHIC MACROFAUNA OFFSHORE

3.5.1. Introduction

Predictions of effects on benthic communities from activeties related to the development of the Heidrun field will mainly be based on previous results from environmental monitoring of similar offshore operations in the North Sea. We shall have to consider, however, modifications due to differences in:

- pollutant load
- sediment characteristics
- benthic-fauna characteristics
- depth
- water-current regime

3.5.2. Zones of effects on benthic fauna around drilling and production platforms

The data obtained in several monitoring programmes undertaken to assess the environmental effects of drilling operations in the North Sea has been reviewed by Addy *et al.* (1983) and Davies *et al.* (1984). The basic similarity in environmental effects resulting from the discharge of material from drilling and production platforms has led to the concept of "zones of effect":

ZONE I is characterised by an "impoverished and highly modified benthic community". Sediments beneath and very close to the platform may consist only of cuttings and associated drilling fluid particulates, with no benthic fauna. The zone can extend up to 500 meters from the platform.

ZONE II is termed the "transition zone" in relation to benthic diversity and community structure. The maximum extent of this zone can vary between 200 meters and 2000 meters.

ZONE III is characterised by elevated levels of chemical (and possibly physical) contaminants although there are no detectable effects on the benthic community structure. The zone can be described as "contaminated" rather than "polluted", and can extend ca. 800 meters to 4000 meters from the platform.

ZONE IV represents the natural, undisturbed sediment where baseline or background values are obtained for measured parameters, and where there is no detectable effects of drilling activity.

Obviously, the areal extent of these zones varies between platforms and with time. The extent of biological effects appears to be greater from the use of oil-based drilling muds than from water-based muds.

In a recent investigation in the Murchison field (Mair et al. in prep) indications of macrobenthic recovery was observed following the termination of drill-cuttings discharges. Pre-operational surveys took place in 1978-80. An operational-phase survey took place in 1982, and a post-oerational survey in 1985, 16 months after the termination of discharges. The results showed strongly reduced species abundance and diversity at 100-250 m distance from the platform in 1982. At 1000 m in 1982 and 2000 m in 1985, the values were within ranges of background levels. Species abundances and diversity had improved greatly at 100-250 m in 1985 but had decreased slightly at 500-1000 m. The outer limits of the spread of the "transition" zone had moved from around 500 in 1982 to approxinately 1000 m in 1985. There were also an inward spread of the "transitional zone" to the 100 m station in 1985, displacing zone of highly modified fauna found in 1982.

3.5.3. Oxidation-reduction transition zone in sediment

The surface layers of sediments underlying waters of the open sea are usually well oxygenated and support a benthic fauna community which is frequently abundant and diverse. Metabolic processes at the macrofauna and microfauna levels are predominantly aerobic and the supply of carbon/nitrogen/phosphorus is usually the rate-limiting factor.

Diffusion of oxygen from the surface to the deeper sediments is restricted by the physical barrier of the sediment matrix. Eventually, with increasing depth, the rate of oxygen consumption by aerobic respiration (i.e. the oxygen demand) exceeds its rate of supply and anoxic conditions are established. The depth within the sediment at which this change takes place is commonly referred to as the "oxidation-reduction transition (ORT) zone". Below this zone, metabolic processes are anaerobic, largely confined to the microfauna and, in marine sediments, are usually dominated by sulphate-reduction.

As the majority of benthic macrofauna species require oxygen, the depth at which the ORT zone occurs approximately delineates the lower extent of the sediment which is able to support a normal (aerobic) ellicit modification due to changes in water movement in the immediate vicinity of the installation.

Grain-size characteristics of Haltenbanken sediments are treated in chapter 3.4.

3.5.5. Total organic carbon (TOC) content in sediment.

The TOC content of sediments is usually directly related to grain-size. Fine sediments are characterised by higher TOC contents than coarser grain sediments. The medium- and fine-grain sandy sediments typical of the North Sea plateau contain TOC in amounts of approximately 1% or less. Dicks (1976) for example, obtained TOC contents of 0.27-0.84% for sediments from the Ekofisk area. Moore (1983) reported values of 0.15-0.50% in the vicinity of the Beryl oilfield. Oppenheimer et al. (1977) found TOC contents in the range 0.1-0.6% in surface sediments from a wide area of the North Sea. Drilling platform discharges may cause elevated sediment TOC originating from hydrocarbons in the drilling mud or from other sources like domstic wastes.

TOC contents in Haltenbanken sediments were in the range of 0.25 to 0.55% (Bowler et al., 1986a).

3.5.6. Effects of barit on benthic communities.

The most important source of discharge from drilling operations is barite ($BaSO_4$). Barit is used in very large quantities to increase density in mud formulations, it can comprise up to 90% of the total mass and be present in concentrations of 200 g/kg. It is a very useful marker for monitoring the extent of dispersion of discharged mud and cuttings, especially in view of its particulate nature, its low solubility in water, its persistence in nature (i.e., it is not biodegradable) and its resistance to resuspension once deposited (Trocine and Trefry, 1983).

According to the available literature, barium in the form of the highly insoluble sulphate (i.e., barite) does not constitute a direct toxicological hazard. It should be noted, however, that the barium sulphate is in the form of very fine particulate material (grain-size of less than 60 µm): the incorporation of such fine material to a surface sediment will change the grain-size distribution characteristics. This effect would be most significant in areas comprising predominately of sand, where the diffusion of oxygen to deeper sediments would become more restricted and thereby poterntially affecting the sediment fauna population. The addition of barite to a sandy sediment has been found to reduce the abundance of most meiofaunal species and to inhibit recruitment of macrofaunal polychaetes and molluscs (NAS, 1983). In the Heidrun field region the sediment consists predominatly of muds and the grain-size distribution is therefore probably less affected.

3.5.7. Hydrocarbon contamination and benthic communities

Total hydrocarbon (TOC) contents in the range 4-9 mg/kg dry sediment have been reported for uncontaminated sediments from the Brent, Beryl, and Forties oilfields, and from 'control' stations in the North Sea (Massie et al., 1981). Oppenheimer et al. (1979) found baseline hydrocarbon contents in the range 4-45 mg/kg in sediments from various locations on the North Sea plateau. Addy et al. (1983) reported background levels of sediment hydrocarbons of about 1 mg/kg near Statfjord, and in the range 30-50 mg/kg at other locations in the North Sea. In unpolluted sediments of the southern North Sea, Law and Fileman (1985) found total hydrocarbon contents of up to 10 mg/kg, with the higher contents in the range ususally asociated with finer-grained sediments.

The range of total hydrocarbon contents found in the Haltenbanken 1985 survey was 0.4-11.2 mg/kg dry sediment (Bowler et al., 1986a), quite consistent with published values for unpolluted sediments in the North Sea.

The toxic and carcinogenic effects ascribed to mineral oils are usually attributed to aromatic compounds, although there is an increasing body of evidence to suggest that high molecular weight hydrocarbons in general are potentially toxic at very low concentrations. In their review of the environmental effects of oil-based drilling fluids, Addy et al. (1983) stated that concentrations of 100 mg/kg diesel oil "would be expected to cause significant detrimental effects on the biological community of the seabed".
The drilling fluids used on some wells are based on a highly refined, low-toxicity mineral oil. According to one report, the low-toxicity oil-based systems commonly avilable in the North Sea are between 2 and 60 times less toxic than diesel-based systems (Anon., 1983). Referring to data given by Addy et al. (1983), this would imply that sediment hydrocarbon concentrations in the range 200-6000 mg/kg or more could be expected to show detrimental environmental effects in situations

where low-toxicity mud systems are in use.

Addy et al. (1983) have reported increases in the TOC content in excess of 1000 times background levels in sediments within 500 m of drilling operations in which oil-based drilling fluids have been used.

On a cautionary note, it must be stated that "detrimental effects" on the benthos community are not limited to aromatic hydrocarbon toxicity. Bowler et al. (1987) made reference to the possibility of ecosystem damage due to other factors associated with offshore drilling practice (e.g., sediment grain-size modification, organic enrichment, changes in redox-profiles, accumulation of heavy metals).

3.5.8. Characteristics of the surface sediments and benthic fauna on Haltenbanken

A comprehensive and detailed description of the surface sediments and fauna on Haltenbanken was given by Bowler et al. (1986a). A brief summary:

- The range of values obtained for many of the parameters investigated was wide but this was not unexpected when the large area covered by the survey is taken into consideration.

- The absolute values obtained for the parameters investigated were in good agreement with those reported elsewhere for unpolluted sediments from the Norwegian Sea and North Sea.

- For the majority of parameters, the distribution of values was normal and random, with very little evidence for zonation within the survey area.

- There was no evidence to suggest that sediments at any of the sampling sites had been influenced by drilling operations carried out up to the time of sampling (May 1985). Sampling sites were located at least 3 km from existing well-sites.

Fauna

The majority of stations was characterised by a total population in the fairly broad range of 100-500 individuals (per 0.5 m^2), representing 40-80 taxa. In most cases, the distribution of individuals and taxa between stations was both normal and random. There was little evidence of geographical zonation of the survey area on the basis of these parameters.

Values for population diversity (Shannon-Wiener index) and evenness covered a relatively wide range but were not atypical for natural communities.

Several organisms which are usually associated with sediments suffering moderate or severe organic pollution were recorded. They were quite randomly distributed and occurred in low abundance. Their occurrence in the Haltenbanken sediments is considered to reflect their natural ubiquity.

The polychaetes were the most common and abundant organisms, followed by nematodes and sipuncula species. The dominant components of the benthic macrofauna population in the Haltenbanken sediments appear to be unique for the area, although there were certain similarities to those in the sediments from the Trænabanken concession area to the north (Fritzvold, 1982). It should be noted that according to published data there is a wide variation in the composition of the benthic macrofauna community throughout the North Sea and Norwegian Sea.

There appeared to be no significant zonation of the survey area on the basis of macrofauna community composition. The distribution of the majority of sampling stations according to fauna population composition was relatively normal and random.

The benthic fauna population at the sampling sites selected for analysis displayed features typical for natural communities and were not measurably affected by drilling operations performed up to the time of sampling. The data can therfore be considered to reflect natural/background characteristics.

At station 4 (the station closest to the Heidrun field, se fig. 3.4.1), a total of 86 individuals were found (in 0.5 m^2), representing 35 taxa. Station 4 is one of six stations located in the north of Haltenbanken. The lowest number of individuals and taxa were associated with these stations. The most abundant species at station 4 were the bivalve Nucula corticata and the polychaete, Spiophanes kroeyeri.

Epibenthic macrofauna have not been investigated in the Haltenbanken area. The benthic amphipod fauna of the West-Norwegian continentl shelf has however, been investigated and compared with the fauna of adjacent fjords (Buhl-Jensen, 1986). The two stations most relevant for the Heidrun fieled (7, 23) region are located at somewhat deeper water (398-484). Diversity at these two stations were 3.04 and 2.32 respectivly. The investigation concludes that diversity is correlated with bathymetric isolation, distance from shelf slope break, depth and mean grain size of the sediment.

Comparing Heidrun and Haltenbanken with other areas

Some similarities and differences between Heidrun/Haltenbanken and other areas (mostly in the North Sea) are summarized in tabel 3.5.1 and 3.5.2.

Table 3.5.1. Dominating species and diversity (H) in the uneffected area of 13 filelds.

Locality Year (Author)	Depth (m)	%Mud (<63 um)	Dominating species (UNPOLLUTED SECTOR)	Diversity (H)
Heidrun 1985 (Bowler *et al.* 1986a)	330	79	Nucula corticata Spiophanes kroeyeri	4.8
Haltenbanken 1985 (Bowler *et al.* 1986a)	220-390	36-95	Spiophanes kroeyeri Onuphis quadricuspis	2.3-5.9
Trænabanken 1982 (Fritzvold 1982)	ca. 300	40-82	Spiophanes kroeyeri Limopsis minuta	4.6-5.6
Statfjord 1986 (Miljøplan 1987)	143-160	0.4-4.6	Exogone verugera Caulleriella spp. Euchone incolor	4.4-5.8
Gullfaks 1986 (Rygg *et al.* 1986)	130-140	2.0-6.2	Limatula subauriculata Echinocyamus pusillus	2.8-4.6
Oseberg 1986 (Bowler *et al.* 1987)	100-125	0.1-1.0	Spiophanes bombyx Spiophanes kroeyeri	4.4-5.2

Table 3.5.1 (Continued)

UNPOLLUTED SECTOR

Locality Year (Author)	Depth (m)	%Mud (<63 um)	Dominating species	Diversity (H)
Odin 1985 (Vogt *et al.* 1985)	100	0.6-2.4	Hippomedeon denticulatus Timoclea ovata	3.3-5.4
Frigg 1986 (Bowler *et al.* 1986b)	104-106	0.4-1.4	Owenia fusiformis Myriochele oculata	4.6-4.8
Heimdal 1986 (Bowler *et* *et* al. 1986c) 5.1-5.3	120-125	10-14	Myrochele oculata Thyasira croulinensis	
Ula 1984 (OPRU 1984)	65-70	2.0-3.4	Scoloplos armiger Myriochele spp.	3.4-4.7
Ekofisk (inkl. Eldfisk, Tor) 1984 (Howard and Hannan 1985)	70-76	0.7-10(23)	Chaetozone spp. Spiophanes bombyx	3.0-5.2
Valhall/Hod 1985 (Johannessen *et al.* 1986)	65	0.1-3	Nephtys ciliata Goniada maculata Myriochele oculata	2.6-4.2
Forties 1978 (Hartley 1984)	100-125	3.2-40	Amphiura filiformis Eclysippe sp. Thyasira equalis	4.4-5.9

Table 3.5.2. Domenating species and diversity (H) in the polluted area surrounding selected oil fields.

	POLLUTED SECTOR		
Locality Year (Author)	Dominating species	Diversity (H)	Extension of effects (max. distance from platform, m)
Statfjord 1986 (Miljøplan 1987)	Ophryotrocha spp. Capitella capitata Rhaphidrilus sp.	0.3-5.0	1000-2500
Oseberg 1986 (Bowler et al. 1987)	Capitella capitata Cirratulus cirratus	0.7-4.9	750-1500
Heimdal 1986 (Bowler et al. 1986c)	Pseudopolydora sp. Chaetozone setosa	5.0	250-500
Ekofisk (inkl. Eldfisk, Tor) 1984 (Howard, Hannan 1985)	Capitella capitata	0.1	150-450
Valhall/Hod 1985 (Johannessen et al. 1986)	Capitella capitata Nereimyra punctata	0.7-3.6	250-2000

3.5.9. Predicting benthic pollution at Heidrun

Previous results from environmental monitoring of offshore operations in the North Sea have shown that the most severe environmental impacts are related to discharges of oil-based muds and associated cuttings. Muds based on diesel oil as well as 'low-toxicity' oil may cause pollution effects extending 1 km or more from the discharge points (e.g., Statfjord). The effects on the seabed will be less severe if water-based muds are applied or if the used mud and cuttings are collected and shipped for disposal onshore.

A main difference between the sediments of Heidrun/Haltenbanken and the North Sea fields is the mud content. The proportion of mud is very much higher on Heidrun/Haltenbanken. Deposition of oily mud and cuttings onto these silty sediments may cause effects that differ from the effects observed on sandy sediment fauna in the North Sea. In a field experiment, Bakke et al. (1985) found that contamination by oil-based drill cuttings had a less severe effect on fauna inhabiting a sediment which contained 12% mud than on fauna inhabiting a sediment which contained 2% mud.

More information from case studies involving pollution of muddy sediments is necessary if a proper prediction for Heidrun/Haltenbanken is to be given.

The greater depths on Haltenbanken may cause the discharges to spread out more extensively before they reach the bottom than they do in shallower areas. The spread-out will also be influenced by the current-water regime. In general, extensive spread-out will enlarge the area of contamination, and smooth the gradients of impact within the area.

3.5.10. Conclusions.

Predictions of potential effects on benthic communities from the activities related to the development of the Heidrun field are based on previous results from monitoring similar offshore operations and considering the special conditions on the Heidrun field.

The basic similarity in environmental effects resulting from the discharge of material from drilling and production platforms has led to the concept of "zones of effects". Four zones are distinguished.
(1) This most affected zone can extend up to 500 m from the platform and contains an impoverished and highly modified community.
(2) This zone is a transition zone in relation to benthic diveristy and community structure. The maximum extent of this zone can vary between 200 m to 2000 m from the platform.
(3) This zone show no detectable effects on the benthic community. However, traces of physical and chemical contamination can be detected. This zone can extend 800 to 4000 m from the platform
(4) No contamination can be detected. The benthic community is not affected and is similar to background community.

The depth of the layer of oxygenated sediment determines to a large extent the benthic community in an area. The discharge from drilling and production operations (cuttings, drilling fluids, cement hydrocarbons, domestic wastes), will both by reduced diffusion (physical effect) and increased oxygen demand (aerobe metabolism) reduce the depth of the oxygenated layer and thus effect the benthic community.

Experience from other fields indicates that the discharge of drill cuttings with associated drilling mud is the main cause of effect on the benthic communities especially when oil based drilling mud is used. Where low-toxicity mud systems are used, hydrocarbon concentrations in the range 200-6000 mg/kg in the sediment are expected to show detrimental environmental effects.

The benthic communities in the Heidrun field were for the majority of parameters in good agreement with those reported for unpolluted sediments from the Norwegian sea and the North Sea. There was no evidence suggesting that sediment or fauna were influenced by drilling operations performed before May 1985.

The higher mud content and the larger depth may cause effects on the benthic community not predictged by experience from the North Sea. Such effects could a priori be more severe because the balance between oxygen consumption and oxygen availability will be more significant. On the other hand species in a muddy environment are often more tolerant to low oxygen conditions than species in areas with sand and silt. Thus, more information from case studies is necessary if more reliable predictions for environmental effects in the Heidrun field area are to be given.

3.6. SEABIRD POPULATIONS

The data base for seabirds in the offshore environment is very poor compared to the coastal region where large scale distribution of the diffrent lifestages are relativly well documented. The physiological effects of oil on seabirds are basicly the same both offshore and in the coastal region. Because of this we have choosen to present all the information on seabirds together in Chapter 5.6 in the Inshore section.

3.7. MARINE MAMMALS - OFFSHORE

3.7.1 Introduction

This chapter describes the offshore species of marine mammals potentially affected by the planned petroleum activities on the Heidrun field. The species of marine mammals found offshore in this area are basically all whales. Other species of mammals (seals) are treated in chapter 5.7. The present chapter also contains a review of effects of oil exploitation activity on marine mammals in general and this section is also relevant for mammals in the inshore area (chapter 5.7).

The consequences for marine mammals of oil pollution and related activities have previously not been seriously evaluated in connection with any of the petroleum activities in Norwegian waters.

It was possible to perform the present impact assessment on marine mamals because of the considerable experience in practical/experimental and theoretical work related to effects from petroleum industry on mammala in the Bioenergetic Group at the University Oslo.

A recent review of the litterature on the effects of petroleum on marine mammals has been compiled by this group (Griffiths et al. 1987). This review is used extensively in the present work, both as excerpts and by reference.

3.7.2. Large whales

Norwegian waters provide habitat for 7 species of large whales, the fin, sei, minke, blue, sperm, humpback and Greenland whale. Unfortunately publishable population size estimates are available for only one of the species, the minke whale, for the Atlantic ocean (N. Øien, pers. comm.; Benjaminsen, Berlund, Christensen, Christensen, Huse and Sandnes, 1976). With the exception of the sperm and bowhead, these whales are rorquals, and are strong swimmers with long seasonal migrations (Jonsgård, 1966a). The blue and sei whales probably feed exclusively on pelagic crustaceans (krill). Fin, minke and humpback eat krill and various fish, and minke whales take even larger fish such as cod, saithe and haddock. The food of the sperm whale comprises squid and octopus from mid- and deep-water, and benthic fish (Caldwell, Caldwell and Rice, 1966). The great increase in krill abundance in high Arctic waters during the spring and summer months takes the whales northward in a feeding migration. During the autumn and winter the whales move southward in a breeding migration to the warmer waters of the north Atlantic, where birth and mating occur. The information given here regarding distribution has been collected mostly from whaling reports and is not necessarily comprehensive. In addition, the distribution described here may include regions in which whales are now seldom seen, but these areas can be expected to be reinhabited as stocks increase.

The Greenland or bowhead whale (Balaena mysticetus) is a circumpolar species that is extremely rare in the North Atlantic due to several centuries of overhunting. The biology of the species in this region is largely unknown. The Greenland whale and the potential are of distribution of this species are considered unaffected by the Heidrun field development and are not discussed in the present evaluation.

Humpback whale

Humpback whales (Megaptera novaeangliae) have a very pronounced migration cycle that includes passage close to the Finnmark coast (Jonsgård, 1966a). After spending the summer, autumn and early winter feeding mostly on capelin, in the Barents Sea, there is a westward migration from January to March along the Norwegian coast. The whales approach the coast around North Cape and follow it closely as far as Sørøya (Ingebrigtsen, 1929), where they swim westward into the north Atlantic or Jan Mayen/Iceland area. They appear to avoid the North Sea (Slijper, 1962), although very occasionally individuals have been sighted along the Norwegian west coast (Benjaminsen et al., 1976). They again appear in the Barents Sea region in summer, with calves, this time moving eastward further out from land than during the winter. In summer the larges numbers have been observed in the northeastern Barents Sea. Humpback whales have been completely protected by Norwegian law since 1955, and in recent years this species has increased in numbers in north-east Atlantic waters.

Ingebrigtsen (1929) describes two techniques for feeding on krill at the surface. The first technique is to swim around the shoal at great speed, lashing the sea into foam with its flukes. This manouevre concentrates the krill, whereupon the whale dives and envelops the krill from below, breaking the surface. The other approach is to swim in a ring a short distance under the surface while blowing a line of bubbles. This bubble "net" again concentrates the krill for the whale to swallow.

The bulk of the entire humpback population will pass the Finnmark coast from January to March, and again during the summer, this time with sucking calves. Oil from a Heidrun blowout may thus possibly reach migrating humpbacks. The oil drift simulations, however, suggest a very low probability for this to occur.

Factors of possible relevance to the Heidrun field development.

Feeding below the surface may reduce the amount of possible surface oil swallowed during feeding. The whales do not feed during the migratory phase, which should greatly reduce the chance of oil ingestion.

Blue whale

The distribution of blue whales (Balaenoptera musculus) extends throughout the Barents Sea up to the Svalbard region ice edge (80^{0}N) (Jonsgård, 1966a) and southward through the North Sea, although their numbers are still quite depleted. The Barents Sea appears to be an end-stage in a migratory sweep from both the south-west and south-east north Atlantic, with those coming from the south-east Atlantic passing along the Norwegian coastline. The whales reach the Finnmark-Bjørnøya region in June and July and begin the reverse trip south-west in August (Ingebrigtsen, 1929).

Factors of possible relevance to the Heidrun field developmnent.

Single animals and small groups can be expected in the Heidrun field area throughout the year. Blue whales feed primarily on krill.

Fin whale;

Separate fin whale (Balaenoptera physalus) populations are believed to exist off west Norway and in the Barents Sea off north Norway, with little or no mixing between the two (FAO, 1978). According to Ingebrigtsen (1929), there are indications that in March, the northern group approaches the coast of Finnmark from the northern regions of the Barents Sea, and leaves westward in April in a large clockwise circle that takes them past Bjørnøya and Svalbard from May to August, and to eastern Arctic waters for the winter. However, numbers of fin whales have been reported both throughout the summer around Svalbard and in autumn along the Finnmark coast (the latter may be members of the westersn group) (Jonsgård, 1966a).

Concerning the western group, Jonsgård (1966b) reports that fin whales were once seen off western Norway for most months of the year. During the summer migration they fed on krill, but in the winter they followed the schools of Atlanto-Scandic herring during its spawning migration and fed upon herring. They approached the central coast in January and moved south along the coast until April-May before dispersing west or north into the Norwegian Sea. While the size of the northern population is undetermined, there were estimated to be 2.700 in the western group in 1946 and about 400 in 1963. Fin whales have not been caught by Norway since 1968. The locations of whales which were caught from Norwegian shore stations is shown in Fig.3.7.1.

Numbers of fin whales may therefore be expected to occur inside the Heidrun area.

Fin whales feed at the surface but from below. This feeding behaviour may reduce the probability of contact with possible oil slicks. Prey species include both krill and fish possibly reducing the threat of death of prey species after oil.

Sei whale;

This whale (Balaenoptera borealis) is a warm-water migratory species with an irregular distribution around the north Atlantic northward to about 72^{0}N, although they are occasionally seen around Svalbard in mid-summer. The species spends the winter in the warmer Atlantic, where it presumably gives birth in February-March, and migrates north past the Shetland Islands to appear off the coast of Møre about the middle of April (Ingebrigtsen, 1929). Depending on food availability, they may continue north to appear off Finnmark in the beginning of July where they may remain to the end of August. However, catch statistics from the whaling station at Skjelnan, Tromsø, show that sei whales have been seen only sporadically as far north as southern Finnmark since World War 2 (Jonsgård, pers. comm.).

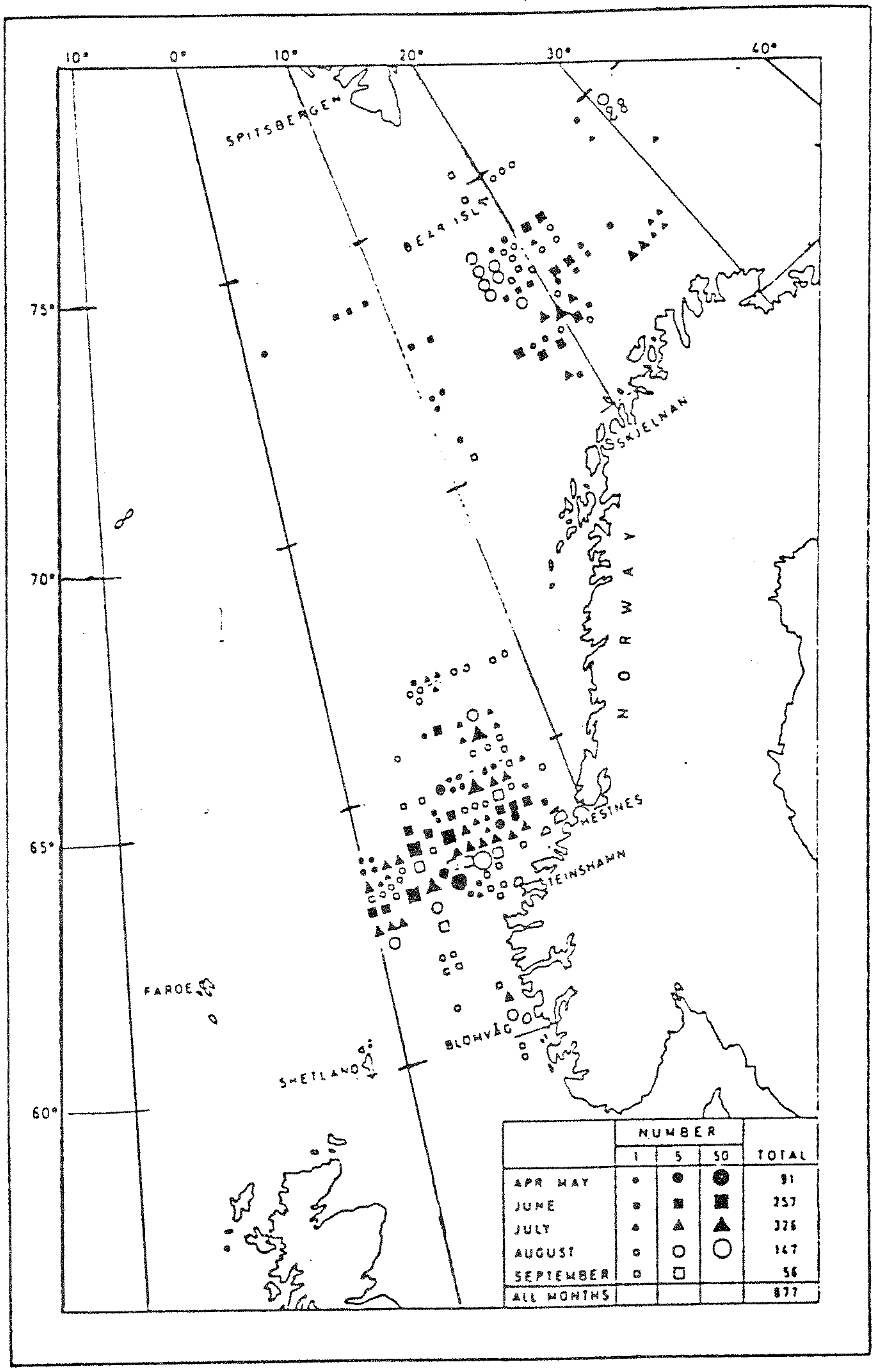


Fig.3.7.1. Location of fin whales caught in the Norwegian and Bartents Sea in association with Norwegian land-based whaling operations.

Ingebrigtsen (1929) has given a description sei whale feeding behaviour. The whale swims at speed and "skims" swarms of krill with mouth half-open and its head above the water. When the buccal cavity is full the whale dives and swallows the food. This technique is in contrast to the blue, fin and humpback, that approach the shoals of prey from below, ingest most underwater, and break the surface from below. It would seem that the sei whale has the possibility to ingest large quantities of oil if it decides to feed in the vicinity of an oil slick.

Factors of possible relevance to the Heidrun field development.

The summer distribution in Norwegian waters is mainly off western Norway. Both females and juveniles may come in contact with oil in case of an oil spill in the Heidrun field since females approaching the West and North Norwegian coasts in spring have sucking calves. Sei whales "skim" the water surface when feeding with possible consequence of oil ingestion if an oil spill should occur. Death of surface krill after an oil spillage could potentially threaten food availability. On the other hand the powerful swimming abilities of the sei whale should enable it to locate alternative krill stocks quickly.

Minke whale;

A presumably separate Northeast Atlantic stock of minke whale (Balaenoptera acutorostrata) is distributed from the British Isles across the North Sea and along the Norwegian coast into the Barents Sea (Fig.3.7.2.), and has been hunted commercially by Norwegian "small-type" whalers since the early 1930's. Recent estimates indicate a total stock between 44.000 and 60.000 whales and an annual average of 2218 whales have been caught from 1938 to 1985. During the last 15 years about 85% of the catches have been taken in the Barents Sea area including coastal waters of Finnmark and Svalbard (Øien, Jørgensen and Øritsland, in press). The northern limit of their range is the edge of the sea ice (Jonsgård, 1966a). A regular migration occurs, southward in the autumn and northward in the spring and early summer, although some younger animals may spend the entire year in the Norwegian and Barents Seas. During the migrations males and females move separately, females and calves usually closer to the Norwegian coast than the males.

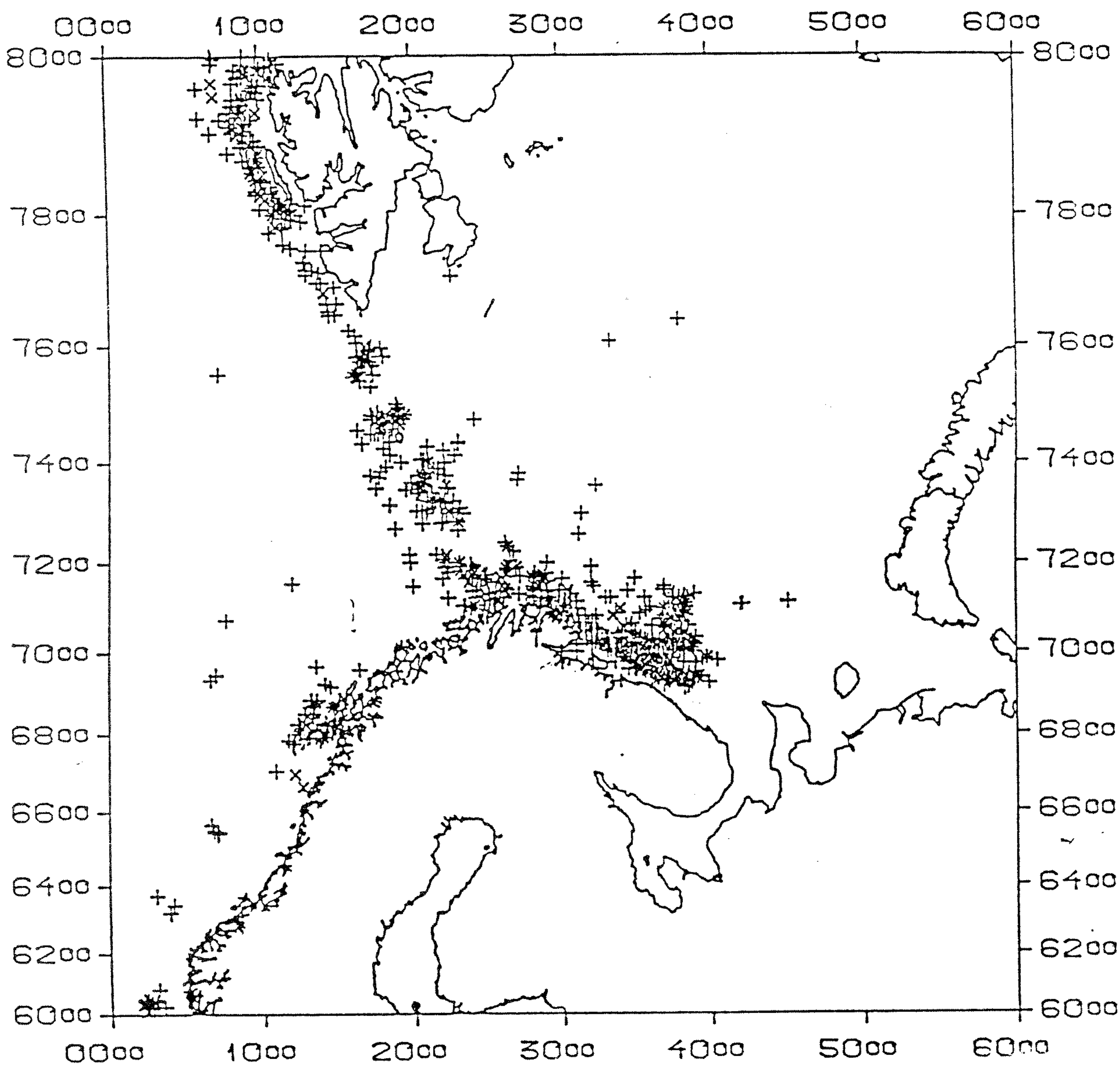


Fig.3.7.2. Distribution of minke whales caught in the Northeast Atlantic during 1980 (Øyen et al. in press).

Factors of possible relevance to the Heidrun field development.

The range of krill and fish species eaten by the minke whale reduces the threat of oil-induced death of prey species.

Sperm whale

The sperm whale (Physeter catodon) is a migratory species with adult males moving north in the summer and south in the winter. A single stock is believed to exist in the north-east Atlantic. In the summer sperm whales are found in deep waters off the continental shelf off Møre and Vesterålen northward to Bjørnøya (Jonsgård, pers. comm.). Puberty in the females occurs at an approximate age of nine years and length of nine metres (Caldwell *et al.*. 1966). Parturition occurs in lower latitudes around the Azores from July to September after a gestation of some 15 months. Lactation lasts for about 24 months. The birth-birth interval is therefore four years.

Factors of possible relevance to the Heidrun field development.

Sperm whales in polar waters are usually single males. The species feed at depth and there is probably little chance of danger to prey species from an oil spill.

Smaller whales

The bottlenose whale, common porpoise, killer whale, and the white-beaked dolphin are the species of smaller toothed whales that could be affected by the Heidrun field development. Most of them have a broad distribution throughout the Norwegian and North Seas. Where no other reference is given, the information supplied in this section comes from Jonsgård (pers. comm.).

Killer whale

Killer whales (Orcinus orca) are cosmopolitan species and are common off the entire coast of Norway. They are especially common in the Møre and Lofoten area where they are often found in harbour and fjords. Migrations are associated with the seasonal movements of the herring schools (Jonsgård and Lyshoel, 1970; Christensen, 1982).

Adult females reach a length of about 5.8 m and males 6.7 m (Christensen, 1984), although lengths of up to nine metres have been recorded (Jonsgård and Lyshoel, 1970). Adults occur usually in small schools of two to four individuals but much larger groups are also seen. There is no definite breeding season and births occur at all times of the year with a peak in late autumn and winter. A variety of species are eaten, mainly schooling fishes, but also seals and other whales (Christensen, 1982).

Bottlenose

This bottlenose whale (Hyperoodon ampullatus) is an inhabitant of deeper waters. In Norway it occurs off the continental shelf off Møre and Vesterålen, but is also seen in the trench area that runs northward, west of Bjørnøya and Spitsbergen, Svalbard. It is a migratory species, moving north in the spring and summer and returning south during the winter. Individuals usually associate with each other in schools, although older males often migrate alone. The species has been protected since 1978 (Benjaminsen and Christensen, 1979).

Adult females are commonly about 7.5 m long and adult males 8.5-9.0 m. Newly born animals are some three metres long. The prey species are fish and cuttlefish. The breeding period lasts from January to June with a peak in April. The gestation period is one year (Christensen, 1973).

Common porpoise

The common or harbour porpoise (Phocaena phocaena) is the smallest of the cetaceans found in Norwegian waters, reaching an adult length of 1.7 m. It is very common along coasts and inshore waters, particularly off the west and north coasts. Apparently there are no long seasonal movements as are found in some other species. Birth and mating occur in the summer from May to July after a gestation of 11 months, and the size at birth is about one half of the length of the parent.

Prey species comprise small fish of various species.

White beaked dolphin

This animal (Lagenorhynchus acutus) is very common off northern Norway, especially in the waters between Finnmark and Svalbard in the summer months. They occur always in flocks, but of highly variable sizes. Like the bottlenose whale, they migrate northwards during the summer months. Birth occurs in the middle of the summer in northern waters, and young are approximately a metre long at birth. Adults reach a length of some three metres. The prey is mostly fish of various species.

Factors of possible relevance to oil pollution:

The small size of several of the species mentioned makes them susceptible to any underwater blasts used during seismic mapping and platform building. The variety of fish and cuttlefish species consumed by nearly all of these whales reduces possible problems from death of prey species after oil spill. The probability of beeing effected by the Heidrun field development is considered very small.

3.7.3. Whale populations vulnerable to oil contamination

By matching available information on the biology and distribution of marine mammals to predictions of the spatial distribution of oil pollution, an attempts is made in this chapter to assess the risks and identify those populations of marine mammals which have the greatest probability of contact with oil. It must not be assumed, however, that direct oil contamination will be the only possible problem that marine mammals may face in the case of an oil spillage. The coastal waters of western and northern Norway are extremely important spawning areas for a number of fish species, and death of fish larvae during an oil spill may, after some delay, produce shortages of prey species for local mammals.

Several smaller toothed whales, minke whales, humpback whales, fin whales and sei whales are considered susceptible to contact with oil in Norwegian waters.

Toothed whales, in particular the killer whale, common porpoise and white beaked dolphin, occur widely and in large numbers in Norwegian coastal waters in all seasons. Bottlenose whales frequent deeper water. All of these species are suceptible to contamination in the case of a platform blowout. Because most shipping accidents happen in harbour areas or within a few kilometers of the coast, where cetacean numbers are not as high, the risk of contact after a shipping accident is lower.

Minke whales are found throughout the Barents Sea to Svalbard and in northern coastal waters during the summer and also in more southern coastal waters during the winter. Some individuals will therefore probably be exposed to oil after spillage from platform or ship, whatever the season or area.

Fin whales are found singly or in small groups in the southern Barents Sea and off the north Norwegian coast during spring, summer and autumn. As the whale and herring stocks recover, fin whales can also be expected to be seen along the coasts and fjords of western and ultimately southern Norway during the summer. Fin whales are therefore included among the marine mammals suseptable to oil in case of an oilspill in the Heidrun field area.

Sei whales occur occasionally during late spring and summer around the Shetland Islands in the southern Norwegian Sea. Some individuals could conceivably come in contact with oil after an oil spillage in the Heidrun field. Sei whales are fast swimming and feed activly in the same manner to the minke whale. The potential for oil ingestion is therefore high.

3.7.4. Specific effects of oil on mammals

Marine mammals are "higher" mammals that are almost certainly capable of feeling pain and fright. The assumption that mammals feel pain in a way similar to humans comes from the similiarity of the pain conducting nervous pathways in the two groups (Dubner and Bennet, 1983) and from the release of identical chemical transmitters and other substances after exposure to noxious stimuli (Hayes, Bennet, Newlon and Mayer, 1978), although animals do not always seem to perceive pain in the same way as humans do (Erickson and Kitchell, 1984). In addition, mammals in pain show characteristic but sometimes subtle behaviours which should allow alert observers to detect the presence of pain (Dubner, 1983; Morton and Griffiths, 1985). This will not be discussed in detail other than stressing that it should be possible to assess whether or not an oiled marine mammals is suffering. This must be considered, both if we decide not to treat an oiled animal, whereupon it may suffer from the irritant effects of contamination, or if we decide to capture and restrain it, whereupon it may suffer from the simple fright of being handled. The treatment and rehabilitation of oiled marine mammals into the wild is more than a matter of scrubbing them with detergent or solvent. In most cases it will involve confinement for several weeks (in the case of polar bears several months) for treatment and restoration of skin oils, and probably the skilled use of tranquillizers, antibiotics and other drugs. Finally, the intense international public interest in marine mammals, along with the certain close coverage of oiled animals by television, will bring strong pressure to ensure that the welfare of animals as individuals is considered. Guidelines for the humane physical and chemical capture, antibiotic therapy and euthanasia of marine mammals already exist, although it is outside the scope of the present evaluation, but will indoubtedly find a place in the management of marine mammals any after future oil spills.

3.7.5 The consequence of long-term oil exposure in mammals

Research projects concerned with oil effects on marine mammals have all been short-term projects. At the same time chronic, i.e. long-term exposure to weathered oil must be considered the actual situation for seals and is already experienced today. Lacking data from realistic experiments and field material the consequences for long-term oil exposure of seals must be judiciously inferred from studies of other species.

There have already been several reviews of the clinical pathology in various species of mammals exposed acutely or chronically to petroleum. Although most of the work relates to fresh or light oils, it is discussed here to give an overview of the types of responses one may expect. Man as well as other mammals react to petroleum exposure in similar ways.

Enteritis (inflammation of the intestine) is a common occurance, due to the direct irritant action of petroleum on the gut mucosa. This effect is common in ruminants (Juck, 1981) and has been discussed in relation to intoxication of polar bears, otters, and phocid seals (Griffiths et al. 1987, Babin and Duguy 1985). Signs exhibited include vomiting, haematemesis (vomiting of blood) and melaena (blood in faeces) (Juck, 1981). Lighter petroleums such as gasoline may actually have their greatest action through the lung, even after swallowing, due to the very high vapour pressure generated by warming the fluids up to body temperature (Carnevale & al. 1983). The effects of inhalation of petroleum products are discussed in more detail by Griffiths et al. (1987), but is not considered applicable to the Heidrun field development.

Other clinical effects described include inflammation and degeneration of the kidney (nephritis) and liver (hepatitis) with subsequent loss of function, enlargement and inflammation of the heart with subsequent dysrhythmia (Juck, 1981), and intravascular haemolysis followed by haematuria and haemoglobinuria (Adler & al. 1976). Systematic absorption of benzene and of molecules in the C_9-C_{12} range produces in a number of species degenerative changes in the bone marrow resulting in anaemia (Juck, 1981). It should be noted that this effect was also seen in polar bears coated by crude oil weathered for several days (Øritsland et al., 1981).

Chronic application of petroleum products to the skin may result in inflammatory change (dermatitis) or even neoplasia. Dutton (1934) attributed the irritant effect to teh content of sulphur compounds in the oil, particularly hydrogen sulphide. The resultant dermatitis can be of an exzematoid exfoliating type, with drying, scaling, cracking and flaking of the skin. If the cracking is serious enough there is leakage of extracellular fluid onto the skin surface. This dry form of dermatitis has also been observed after the application of pure hydrocarbon in the absence of sulphur (Foged, 1984). Alternately an acne type of dermatitis may result that is more pustular. In one study in Poland, such an acne condition was found in 68% of people working with oils and petroleum-based coolants in a machining works (Santarius-Kaczur, 1984). Other research has shown that the lighter fractions of petroleum are also very irritant to the skin. Benzene application caused dermal fibrosis in rats while application of slightly heavier molecules resulted more in the effects described above (Dutton, 1934). Topically applied kerosene has caused hair loss in the horse and severe dermatitis in cattle (Juck, 1981). Considering the consistent history of pathology after the application of hydrocarbons to skin, it is surprising that there have not been any reports on similar results in pinnipeds after coating with crude oil. It may be that in the few trials that have been made, the oil has not been left on long enough to produce an effect.

Hydrocarbons can be extremely irritant if they find their way into subcutaneous tissue, depending on the size of the molecule involved. Such situations have been described in people after accidents with appliances that use solvents under high pressure and after the intentional but misguided injection of petroleum. In some cases, for example when kerosene is used, reaction is immediate, although it is noteworthy that oil may lie dormant for long periods before causing inflammation. In a particularly interesting but extreme case, two men in their mid-60's were treated for purelent cellulitis of the scalp with draining sinuses after having received subcutaneous injections of paraffin oil for pattern baldness some 30 years previous (Klein & al. 1985). In another case, subcutaneous injection of five millilitres of kerosene resulted in abscess formation followed by ulceration (Qaryoute, 1984). Other cases of abscess formation have been reported after the injection of kerosene (Rubenstein & al. 1985).

One feature that really only becomes apparent after long-term exposure to oil is its neoplasia producing ability. An increased incidence of various cancers and tumours, both at the site of oil exposure and distant to it, has been described repeatedly among workers in the petroleum industry (Savitz and Moure, 1984). As an example, two studies in the United States revealed that the incidence of lung cancer among oil refinery workers was 1.6 and 3.0 times higher than in the general population. Other studies revealed, however, much weaker associations. There is better agreement that lymphatic and haemopoietic tumours (For example lymphoma and leukemia) occur more often among oil industry workers. Other neoplasias that have been reported as being relatively more common after hydrocarbon exposure are brain tumour and stomach cancer (Thomas & al. 1984), skin cancer (Purde and Rahu, 1979), Sertoli cell tumour (Mills & al. 1984) and bladder carcinoma (Mommsen and Aagard, 1984). Neoplasia was not limited merely to those people who had had direct contact with petroleum. In one study in the Netherlands, it was found that children of women employed in the petroleum industry whilst pregnant, developed leukemia at a rate two and a half times greater than in the general population (van Steensel-Moll & al. 1985). One possible effect that has not been investigated in this chapter is hormonal disturbance. Ingestion of oil by seabirds raises plasma corticosterone and thyroxine concentration and can lead, through endocrine disfunction, to retardation of growth, impairment of osmoregulation and hypertrophy of adrenal and nasal gland tissue (Peakall & al. 1981). We have not found information in the literature on disturbance of reproductive or other hormonal homeostasis by petroleum. Either it has not been investigated or there is no effect. This subject should be investigated as part of any future study of the effects of oil in marine mammals.

Griffiths et al. (1987) stress that both acute intoxication by and chronic exposure to petroleum products can produce a much wider range of pathology than that which has been previously described in marine mammals. I do not suggest, of course, that the oil effects described here will become common in the Heidrun influence area after establishment of a petroleum industry there. At the same time one must be prepared to discover other effects if a necropsy is performed.

3.7.6. Oil and whales.

Compared with the information available on the effect of oil on seals little is known about the effects on whales. Actual observations of whales in spill situations are very few and seem to indicate that at least the large whales and some dolphins either do not recognize floating oil or are not disturbed by it, for they continue to feed and exhibit other normal behaviours in its presence. Griffiths et al. reviewed the available literature and information in detail and conclude that both large whales and smaller dolphins will not be threatened by transient contact with floating surface oil after a spillage. While smaller toothed whales were shown to be able to detect and avoid thicker layers of floating oil under optimal conditions, oil at sea would quickly form layers too thin to detect. There are also examples from actual spills where dolphins did not avoid spilled oil and continued to feed in its presence. Larger whales have also been seen swimming and feeding in oil-stained water. However, Geraci and St. Aubin (1982) have shown that even prolonged skin contact is most unlikely to be harmful. The only reservation remaining is the internal effect of oil ingestion. Migrating whales would probably not take in much oil. Actively feeding whales could, however, take in larger quantities. While trace amounts of oil administered chronically to dolphins had no harmful effect, the effect of a substantial amount of crude oil over a short time could be harmful. We refer to the situation in seals, where oral administration of oil to seals under controlled experimental conditions caused little ill effect yet seals have repeatedly died in nature from oil intoxication, particularly if they already had other health problems such as a parasite load. The effects of ingested oil in cetaceans remain unknown. We can surmise, however, that the number of cetaceans that would be killed after an oil spillage would be very low, while the discomfort caused to certain individuals might be significant.

3.7.7. Other effects on marine mammals.

To this point the discussion has been limited to the direct effects of petroleum on marine mammals after contact. However, the development of the Heidrun field will have consequences for the marine mammals of the area long before the first oil is extracted. These other consequences are reviewed here.

Noise

The establishment and operation of drilling platforms, drilling ships and pipelines involves the production of noise under water. Normal service shipping and helicopter traffic involves both over- and under-water noise. We may expect a variety of noise types, not all of which may have effects on the surrounding life, and noise must therefore be characterised before it can be adequately discussed -continuous or intermittent, loud or faint, constant in pitch and intensity or variable. We can in theory divide the possible effects of noise on marine mammals populations into four: (1) The noise may be benign and animals may ignore it. (2) It may be of a loudness and frequency that matches that which marine mammals use for social signalling so that it interferes with communication. (3) It may be of a loudness and duration which initially produces alarm but to which animals may habituate. Finally, (4) it may be of an intermittent and irregular nature to which animals cannot habituate. In the evaluation of the possible effects of noise one can use actual experimental and case data where animals have been exposed to noise, or one can measure the frequency and loudness of produced noise and compare it to the known frequency ranges of hearing in marine mammals.

Noises may be divided into those that directly damage acoustic sensory structures and those that have a non-auditory effect (Turl, 1982). In the former category, damage to auditory structures may be produced by brief exposures to very intense sounds or by prolonged exposure to lower levels of sound. High frequency pure tones or narrow bands of noise tend to produce changes in localized regions of the inner ear, low frequency or random and broadband noise produces changes throughout the cochlea (inner ear). The actual extent of the damage depends on the intensity, spectrum, duration and the exposure pattern of the noise source, and rest periods between exposure significantly reduce the extent of permanent damage. The non-auditory effects of noise are those of physiological stress, with signs similar to those seen after exposure to extreme heat or cold. These responses include a variety of measurable physiological changes, such as increased blood pressure, increased corticosteroid level and increased adrenal gland weight. Prolonged stress of this type can exhaust an animal's resistance to infection and disease and, in extreme cases, can result in death. According to Turl (1982), noise produced at deeper depths affects larger areas than shallow water drilling (for example the Gulf of Mexico), because sound is transmitted better at greater depth. In shallow water, there may be considerable transmission loss at the sea surface and at the bottom.

The mechanism of sound condition to the inner ear varies between the different marine mammals. In dolphins, sound is transmitted through the medulla of the lower jaw through the mandibular joint directly to the inner ear (Norris, 1969). In the larger whales and in pinnipeds, sound is transferred directly through the skull to the inner ear whilst animals are in the water, although aerial sound transmission in seals is apparently typically mammalian (Turl, 1982).

Published measurements of the wavelengths and intensities of underwater sounds generated by drilling platforms are presently limited (Turl, 1982), although there is considerable interest in the subject, particularly in the Beaufort Sea off Canada, which can be expected over the coming few years to considerably increase the amount of knowledge available. Comparison of noise characteristics of oil recovery operations with marine mammal audiograms can therefore be only partially accomplished. In general, the frequency range of noise from offshore oil and gas drilling activities is from ten Hertz to ten kiloHertz with peak source levels between 130 dB and 180 dB (Turl, 1982). Greene, quoted by Fraker (1984) measured levels of noise originating from various ships, aircraft and drilling devices in the Beaufort Sea and found a frequency range of 0-2.000 Hz and an intensity at 100 m distance of 180 dB to 100 dB. After consideration of peak noise output level from platforms and ambient ocean background noise level, Turl (1982) calculated that <u>minimum</u> detection ranges by marine mammals were 38 km at 0.02 kHz and 174 km at 1.00 kHz.

Accurate estimation of the effects of noise on marine mammals is also limited by poor understanding of the frequency range to which these animals are sensitive, particularly at the lower frequencies (Turl, 1982). Hearing sensitivities in large whales have not been measured at all. One guideline presently used is to measure the frequency range of sound production and to assume that animals are at least sensitive to their own frequencies. Four categories of sound are produced by mysticete whales (Turl, 1982). The first include low frequency means of frequency range 12-500 Hz. The second group comprises grunts, thumps and knocks of short duration in the 40-200 Hz range. Group three sounds consist of short, discrete pulses of higher pitched chirps and whistles around 1 000 Hz, while the last sound group is clicks or pulses that have peak enegy at high frequencies, often between 20 and 30 kHz. We can therefore assume that larger whales hear sound at least between 12 Hz and 30 kHz. Actual audiograms of smaller whales and pinnipeds indicate that peak hearing sensitivity of toothed whales occurs between 5 and 100 kHz (the notable exception is the killer whale whose hearing begins to fall away at 12 kHz), and of pinnipeds 1 to 12 kHz.

The conclusion reached by Turl (1982) was that the possibility exists for marine mammals to be disturbed by noise from petroleum activities, in particular during feeding, mating and in protecting the young. The lower frequency sounds produced by large whales are well suited for long-range communication and interference could substantially reduce the detection range. The possibilities for such a disturbance may be very real. Cowles, Hansen and Hubbard (1981) reported that the sounds of large Arctic class tankers will be clearly heard underwater over an area of 30 000 km^2.

These theoretical calculations are supported by actual observation. There is some experimental evidence that whales avoid noise from oil development. Tyack, Clark and Malme (1983) played recordings from a production platform, drilling platform, drillship, helicopter, semi-submersible drill rig and finally from killer whales, to southward migrating grey whales off the Californian coast. Grey whales exposed to killer whale, production platform, helicopter and exploration platform sounds showed an avoidance response and swam away from the source of the sounds, or slowed down in the vicinity of the sounds. Fraker (1984) reported seeing beluga whales within four km of an artificial island drilling site in the Mackenzie Estuary, and bowhead whales three to six km from active drill ships in the Beaufort Sea. All these whales appeared to be behaving normally although the noise level in the area was well above ambient. There is also some evidence that certain areas of the Beaufort Sea, once frequented by bowhead whales, have been abandoned since the establishment of petroleum recovery operations, but adequate survey results are lacking (Fraker, 1984). There is also a suggestion that walrus distribution in the Canadian Arctic may have been affected by the establishment of permanent logistical bases (Cowles et al., 1981).

As a summary it appears that hearing in marine mammals is good and that most species can detect sounds in the 10 Hz to 50 kHz range. There is good evidence that the behaviour of at least some species of whales is altered by high levels of unnatural noise and also some evidence, although unconfirmed by systematic survey, of long-term disturbance of the migration of bowhead whales after establishment of oil operations. The effects of such activities on pinnipeds has not been shown. It is recommended to direct boat and helicopter traffic servicing the Heidrun field platforms into routes which prevents disturbance of local colonies. The effect of animals in the open sea will probably be insignificant. Seals are known to react strongly to certain high frequency noises (Mate, Brown and Greenlaw, 1983) but the amount of experimental evidence does not allow further speculation.

Blasts

By blasts we mean shock waves generated by actual blasting operations, but also the shock waves produced during seismic mapping of the ocean floor in search of petroleum.

It is presently not known whether blasting operations will be carried out on the Heidrun field. The effects of underwater blasts on marine mammals are reviewed by Griffiths et al. It may be concluded that if detonation of explosives is to be used in securing the Heidrun platform to the sea bed, then a number of pinnipeds and smaller cetaceans will almost certainly be killed quickly and others die from injuries, although not enough to threaten any population. According to Geraci and St. Aubin (1980) there is still a large deficiency of information on the effects of blast on behaviour which needs to be filled by experimental studies.

Drilling muds and other chemicals.

A large quantity of various chemicals is used in the drilling of an oil or gas well and eventually these chemicals are usually discharged into the ocean. This section discusses the possible consequences of such discharges.

Drilling muds are fluids used to lubricate the drill bit when a shaft is being bored in the ocean floor. The specific effect of drilling mud on marine mammals has not been investigated, but the direct toxicity would probably be low. It is hard to conceive of a seal or whale being harmed by swimming in the area of an exploration platform. Furthermore, it is not known if there is an appreciable buildup of heavy metals around exploration platforms which then becomes introduced into the food chain and hence seals. If there is any harmful effect it would most likely be as a contribution to the high levels of petroleum and possibly heavy metals in water and sediment in the vicinity of the platform.

Boat and aircraft traffic.

Boats and helicopters are a common sight in the vicinity of petroleum platforms as service vehicles, and are also widely used in the cleanup of any marine oil spillage. It appears that most marine mammals do not react to the presence of vessels until they approach beyond a certain critical distance, after which they actively avoid them. Beluga whales are not disturbed by boats until they are about one and a half miles away, whereupon they move away. In one case all beluga whales within this critical distance moved away from an approaching vessel. Two hours after the vessel's passage there was a strip a mile wide containing no whales, but the whale distribution had returned to normal after 30 hours (Fraker, 1984). There was no evidence of any long-term disturbance of migration patterns. It was suggested that the whales might be reacting with their sonar to the trail of tiny bubbles left in the wake of the vessel. Humpback whales in Glacier Bay, Alaska, also reacted to boat traffic and they possess sonar in the same way that toothed whales do. At ranges between one and two miles whales tended to move away from vessels and at ranges of less than a mile they chose to dive (Fraker, 1984). In another study, humpback whales increased dive times, reduced surface intervals, breached and actively avoided ship traffic, beginning at a distance of over three km (Baker, Herman, Bays and Bower, 1983). In several contrary episodes, humpback whales in the Denmark Strait and the Barents Sea have not reacted strongly to the approach of a ship and in some cases seemed attracted to ships, swimming alongside for periods from several minutes to over an hour (Christensen, Griffiths and T. Øritsland, unpublished observations). California grey whales were reported to have abandoned a lagoon where there was considerable boat traffic, and to have reoccupied it when the boat traffic was stopped (Fraker, 1984). These whales seem, however, to adapt to the close presence of a large number of boats, as indicated by their tolerance of the large number of tourist boats that regularly visit the breeding lagoons of Baja California. One of the authors (D.G.) observed that humpback whales off the eastern coast of Australia consistently dived when a twin-engined survey plane (Partenavia) flew directly over them at a height of 400 m, although they did not react when the plane passed further away. Most whales will probably actively avoid single ships in the open sea by swimming away from them but the disturbance can be expected to be temporary and they will resume their original behaviours once the ship has passed. There may be a threshold amount of boat traffic, as yet undetermined, beyond which permanent changes in behaviour and distribution become established.

3.7.7. Conclusions

The Heidrun field development and operations may cause some disturbances, and in case of any blasting perhaps death of some whales. All over the effect on whales is considered to be insignificant.

The present procedure fore environmental assesments associated with the development of oilfields in a lager area is questionable since the same database is to a large extent applied to one field after another without significant improvement of this database. Such repetition of a limited amount knowledge tends to satisfy both industry and government and in reality prevents research necessary for minimizing environmental impacts. I contend that important environmental concerns could be better managed by using resources present used for environmental assessments more effectively. This is possible by assessing potential environmental effects for several fields together, and use some of the resources now used on overlapping environmental assessments for several adjacent fields, for research which can improve our knowledge in areas were knowledge is lacking.

4. OIL SPILL MODELLING

4. OIL SPILL MODELLING

SUMMARY

The operational oil drift model at The Norwegian Meteorological Institute (DNMI) has been used to present statistical oil drift data for the Heidrun area (position 65°20'N 7°19'E).

The statistics have been obtained from simulated oil drift trajectories, computed by the operational oil drift model. The basic data are historical wind fields for every 6. hours during 1955-1981, from the upgraded Hindcast database at DNMI. In addition a background current field is used. Starting every 6 hour from 1955 the trajectories of oil patches together with the oil amount remaining on the sea surface have been calculated. Every oil patch is simulated during a 30 days period. The statistical information on the oil drift is obtained by analysing all the simulated oil trajectories and amounts for the whole period from 1955-1981. The oil drift statistics have beeen divided into four seasons and for every season presented on five different maps showing the geographical distribution of different quantities:

- Arrival frequency per 10x10 km^2 squares in percent of total number of oil trajectories which are simulated.

- Minimum drift time in unit of days.

- Mean drift time in unit of days.

- Maximum amount of oil in percent of spillage rate.

- Mean amount of oil in percent of spillage rate.

4.1. INTRODUCTION

The drilling activity in Norwegian and adjacent waters has made oil drift prediction increasingly important during the last two decades, and the 1977 "Bravo" blow-out led to the establishment of an operational simulation model at The Norwegian Meteorological Institute (DNMI) which, with some later improvements, is still in use (see Haug and Jensen (1978), Håland et al. (1979), Martinsen (1982), Eide and Martinsen (1984) and Evensen and Martinsen (1986)).

An agreement between DNMI and the Norwegian State Pollution Control

Authorities (SFT) states that DNMI shall provide instant oil drift simulations in case of major oil spills at sea, or in connection with exercises of that kind.

The existing operational simulation model at DNMI is a trajectory type model, i.e. the oil slick is regarded as a single, material point, - for the sake of simplicity and rapidity.

The existing operational simulation model has also been used to present statistical oil drift data for several locations on the Norwegian continental shelf, Martinsen (1985). The basic data are historical wind fields for every 6 hours since 1955.

4.2. BRIEF DESCRIPTION OF THE OIL DRIFT MODELL

4.2.1 The oil drift

Open sea: The model was originally designed for open and deep waters, i.e. oil drift unaffected by coastal areas. For this purpose the socalled "3%-15^0" rule seemed to give fairly good approximation to the oil drift vector. This means that the oil slick drifts with 3% of the wind speed and with a deflection angle of 15^0 to the right of the wind vector. In addition the model superimposes a semi-permanent background current field, which is represented in a 10x10 km grid, see fig. 1.

Coastal waters: Some simple modifications have been done to enable the model to simulate oil drift in coastal waters, although the real conditions in these regions are rather complicated.

The oil drift close to the coastlines is modified in such a way that the vector component perpendicular to the coast reduces to one tenth of its "open sea value".

Moreover, persisting wind and pressure can cause water masses to pile up near the coast, thereby generating geostrophic currents along the coastlines or the continental shelf break. In the model these currents act as time dependent adjustments to the background current field.

4.2.2 The oil mass budget

The procedure for computing the oil mass budget is developed at the Oceanographic Center, Trondheim, Norway. The method takes into account the evaporation of oil and the mixing of the oil into the sea by waves (dispersion), Johansen (1984). The remaining amount of oil is computed by the recursive formula:

$$Q(t) = Q(t-\Delta t)\ F_e(t)\ F_d(W)$$

where :

$Q(t-\Delta t)$: the remaining amount of oil from previous time step

t : the time measured from the start of the actual oil spill

Δt : the time step

$F_e(t)$: the reduction due to the evaporation during the last time step

$F_d(W)$: the reduction due to dispersion during the last time step

W : the mean wind speed during the last time step

The evaporation is based on theoretical studies but are related to the density of the crude oil. Fig. 2 shows the evaporation rate used in the model for various densities of the crude oil.

The factor handling the dispersion of oil is based on empirical results from the "Bravo" blow-out and experience from the Haltenbanken experimental oil spill in 1982. In addition to the wind speed the dispersion also depends on the size of the spill which is characterized by the rate of the spill. The expression used in the model reads:

$$F_d(W) = EXP[-(f_0/4)(Q_0/Q)^{1/2}(W/W_0)^2]$$

where :

f_0 : a reference value

W_0 : a reference value of the wind speed

Q_0 : a reference value of the spillage rate

W : the actual wind speed

Q : the actual spillage rate

In the simulations the reference values are $f_0 = 0.2$, $W_0 = 8.5$ m/s and $Q_0 = 50$ tonn/hour. With an actual wind of 8.5 m/s these values correspond to a percentage reduction per day of 14.6%, 13.2% and 9.5% for spill rates of respectively 80, 100 and 200 tonn/hour.

4.3. OIL DRIFT STATISTICS

The data used in the statistics are information every 24 hour about the position, the drifting time and the amount of oil remaining on the sea surface for all the different simulated oil patches. From these data, geographical fields with different quantities are produced. The different quantities are, arrival frequency per 10x10 km^2, minimum and mean drift time, and maximum and mean amount of oil. The geographical distribution of the different quantities are presented as contour plots.

4.3.1 Interpretation of the statistical presentation

Arrival frequency per 10x10 km^2 area

This plot indicates the geographical distribution of oil trajectories. The unit of the values on the contour lines are per cent of the total numbers of the simulated oil patches. The quantity is not equal to the relative number of oil trajectories passing through the particular squares. This is clearly seen by the low values of the contour lines near the oil spill position. The reason for this is that the information concerning the various oil patches are only used every 24 hours in the statistical computation. In the case of a wind speed of 10 m/s an oil patch , during this time speed, move a distance of approx. 25 km, passing through a few squares before the position is used in the statistics.

Minimum drift time

The unit of the contour lines is days. The plot shows how far away from the oil spill position an oil patch may reach during a time period of 1, 5, 10, 15, 25 and 30 days. The oil spill position is marked with a cross.

Mean drift time

The unit of the contour lines is days. The plot shows the mean distance the oil patches have reached from the oil spill position during a time period of 1, 5, 10, 15, 25 and 30 days. The contour line showing a mean drift time of 1 day is often not drawn. This is because variations in the wind direction may force some oil patches back to the oil spill position increasing the mean drift time above 1 day.

Another feature which must be mentioned is that the contour lines, showing the longest drifting times, for the minimum and mean drift time is nearly similar. This is because the areas are far away from the oil spill position so only one or a few oil patches have reached these areas.

Maximum amount of oil

This plot gives information about the maximum amount of oil which has reached the various locations, i.e. how far away from the oil spill position an oil patch may have an amount of oil of 100, 95, 90, ..., 0 % of the spillage rate. Since the unit of the contour lines is percent of the spillage rate, the amount of oil left at the sea surface is found by multiplying the spillage rate with 6 hours and the percentage value from the plot for the particular locations. This quantity only tells about the amount of oil which have the particular position as the mass center and not the concentration of oil. The oil will be spread over an area which will increase with increasing drifting time. Therefore the concentration of the oil will decrease faster than the values of contours in the plot indicate.

Mean amount of oil

The unit of the countour lines is percent of the spillage rate. The plot gives information about mean amount of oil which has reached the various locations, i.e. how far away from the oil spill position the oil patches may have a mean amount of oil of 100, 95,......, 0 % of the spillage rate. The estimation of the amount of oil left at the sea surface is found in the same way as described in the explanation for the maximum amount of oil. In addition the same comments apply.

4.4 CONCLUSION

The maximum extent of coastline which may receive oil from a spill in the Heidrun field is from Fræna in Møre and Romsdal to North of Senja in Troms. The fastest drifting time from the Heidrun field to the coast depends on season. For the spring, summer, autum and winter the fastest drifting time is 6-8 days, 10-12 days , 5-7 days and 4-6 days respectively. The coastal areas which can be reached within this time are from Flatanger in south to Rødøy in North. The mean drifting time from the Heidrun field to the same coastal areas is 14-15 days, 19-20 days, 15-17 days and 10-15 days for the spring, summer, autum and winter respectively.

ØIL SPILL PØSITIØN: 65°20'N 7°19'E
PERIØD : MAR, APR, MAY 1955-1981
SPILLAGE RATE: 120 TONN/HØUR
DENSITY : 900 KG/M**3

BACKGRØUND CURRENT
UNIT : 25 CM/S PER 10KM

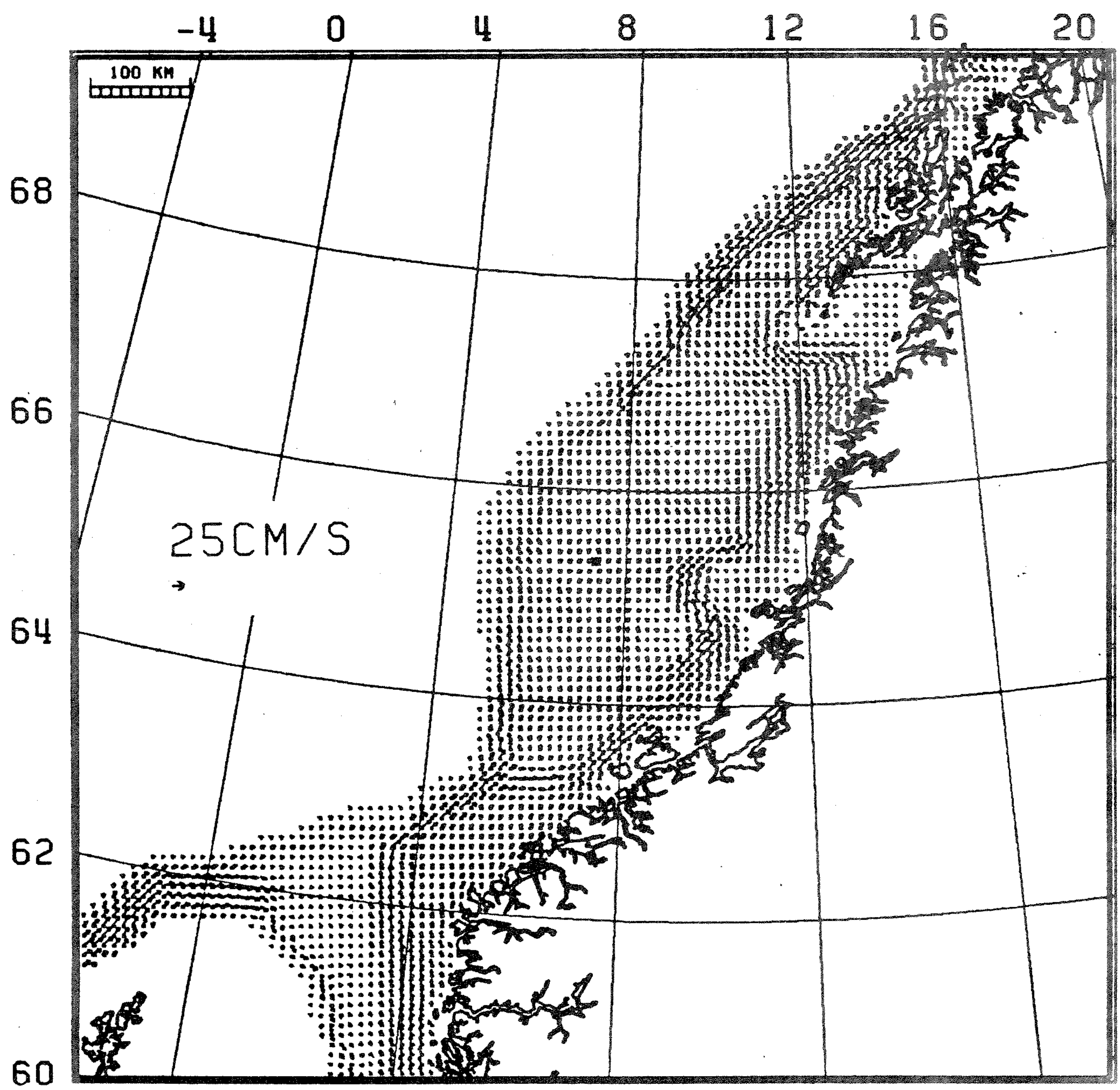


Figure 4.1 The background current field used in the simulations

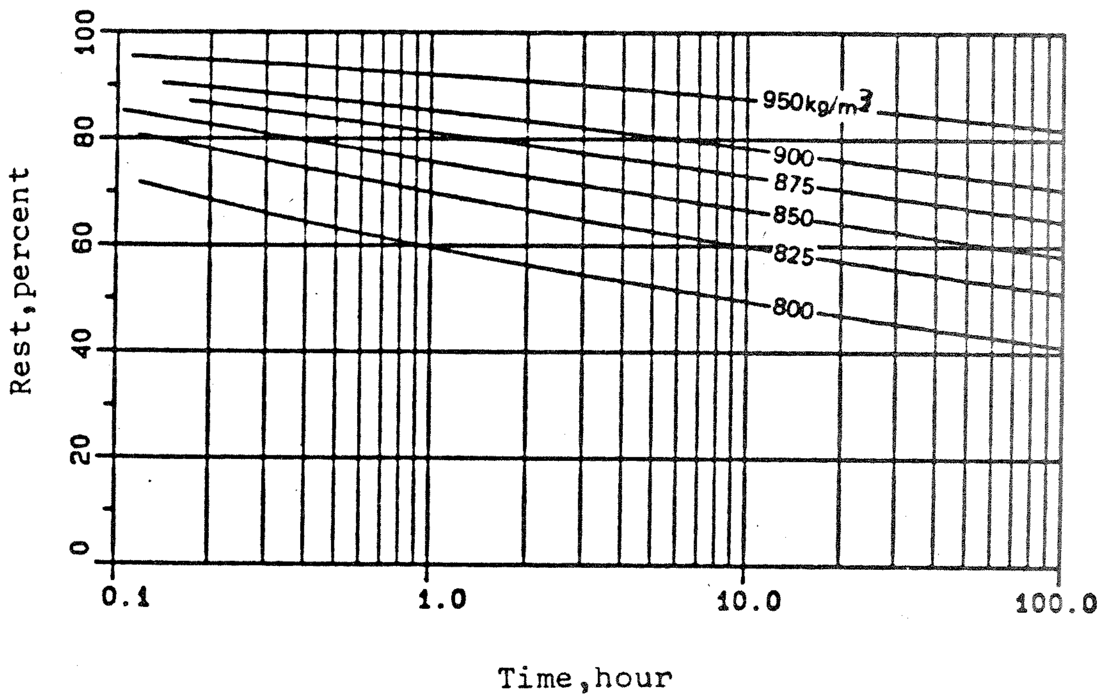
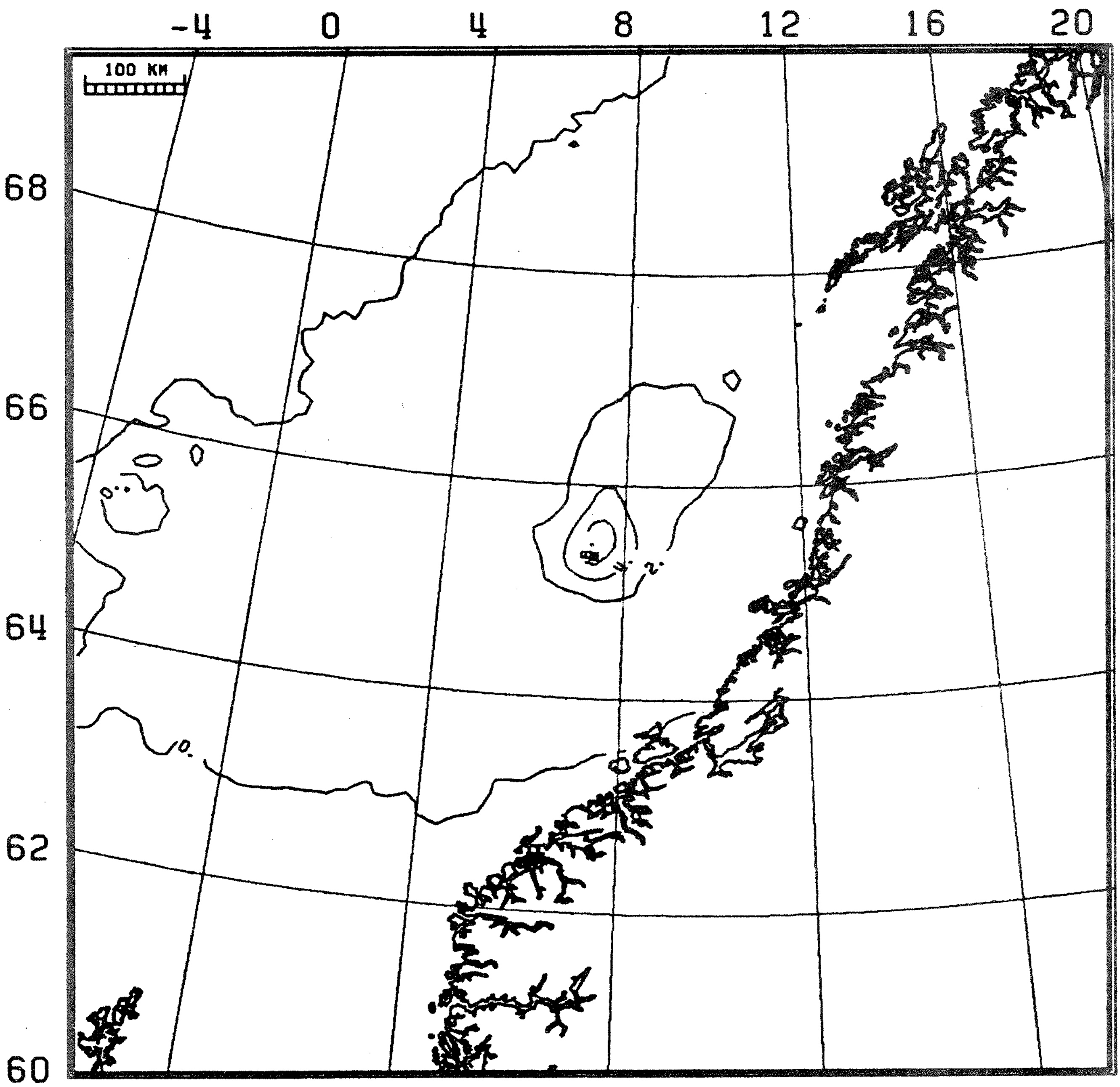


Figure 4.2 The percentage reduction of the amount of oil with respect to time due to evaporation. The values are plotted for various densities of the crude oil.

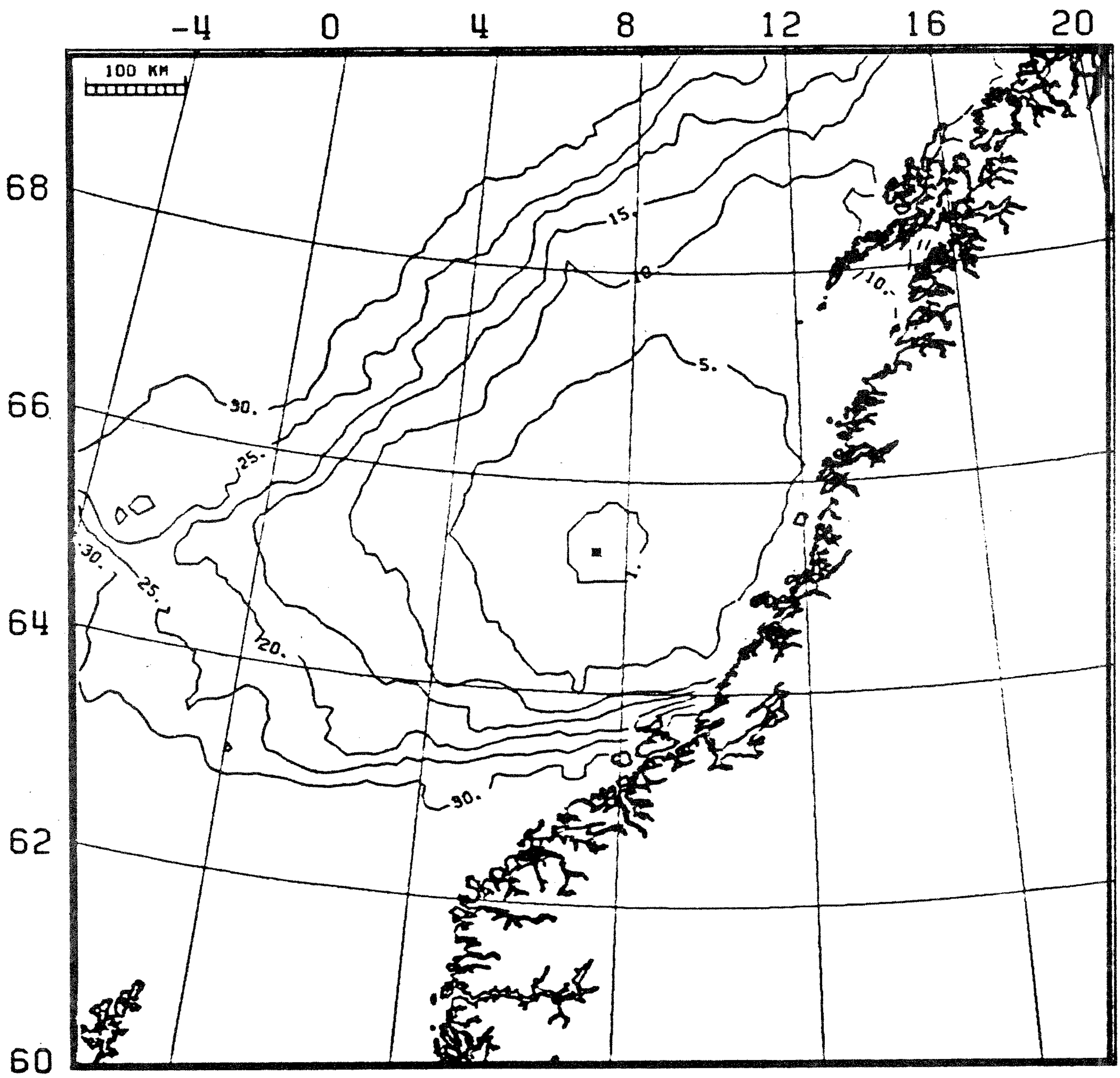
ØIL SPILL PØSITIØN: 65°20'N 7°19'E
PERIØD : MAR, APR, MAY 1955-1981
SPILLAGE RATE: 120 TONN/HØUR
DENSITY : 900 KG/M**3

ARRIVAL FREQUENCY PER. 10X10 KM AREA
UNIT: % ØF TØTAL NUMBER ØF SPILLS



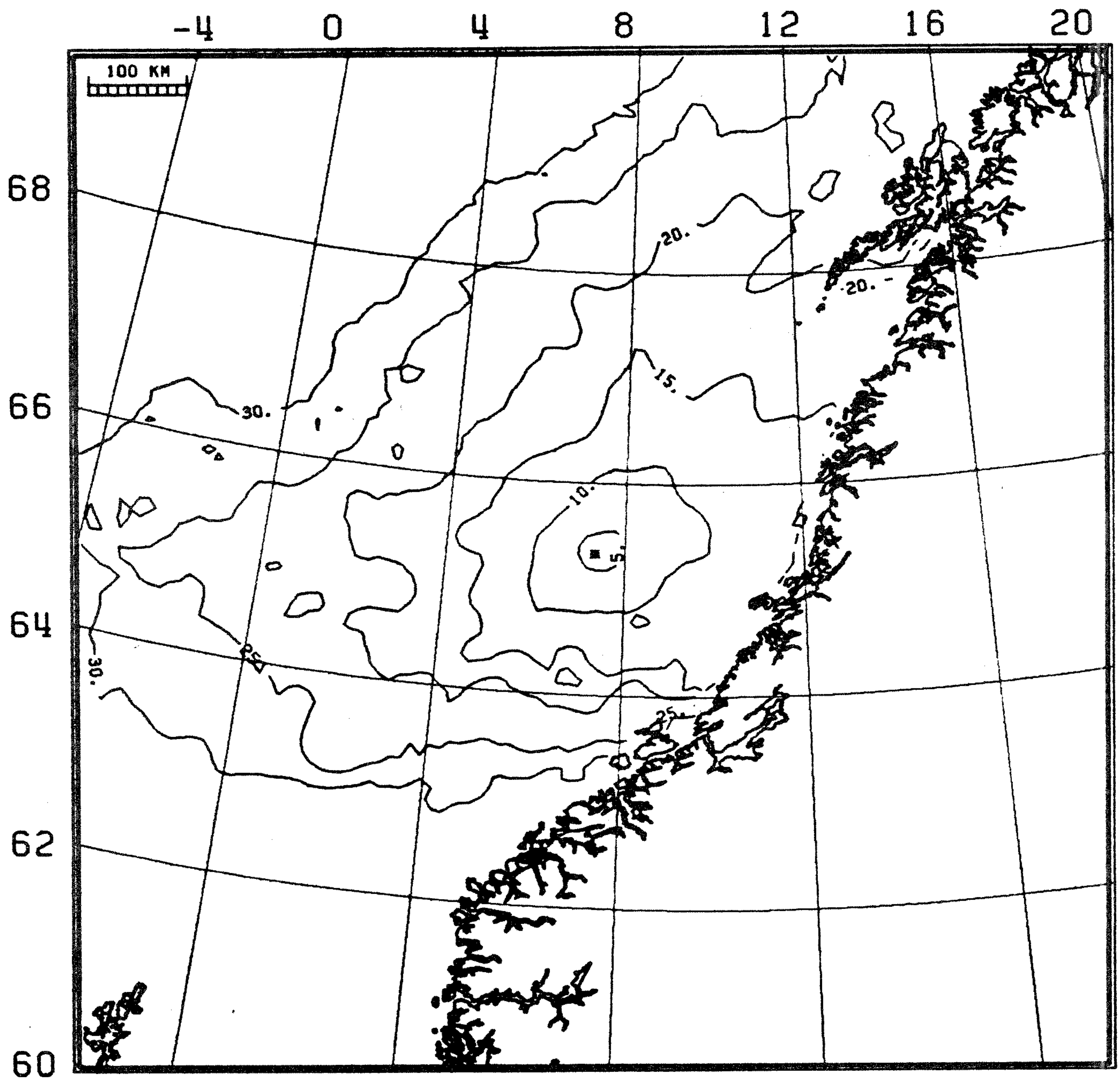
OIL SPILL POSITION: 65°20'N 7°19'E
PERIOD : MAR, APR, MAY 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

MINIMUM DRIFT TIME
UNIT : DAYS



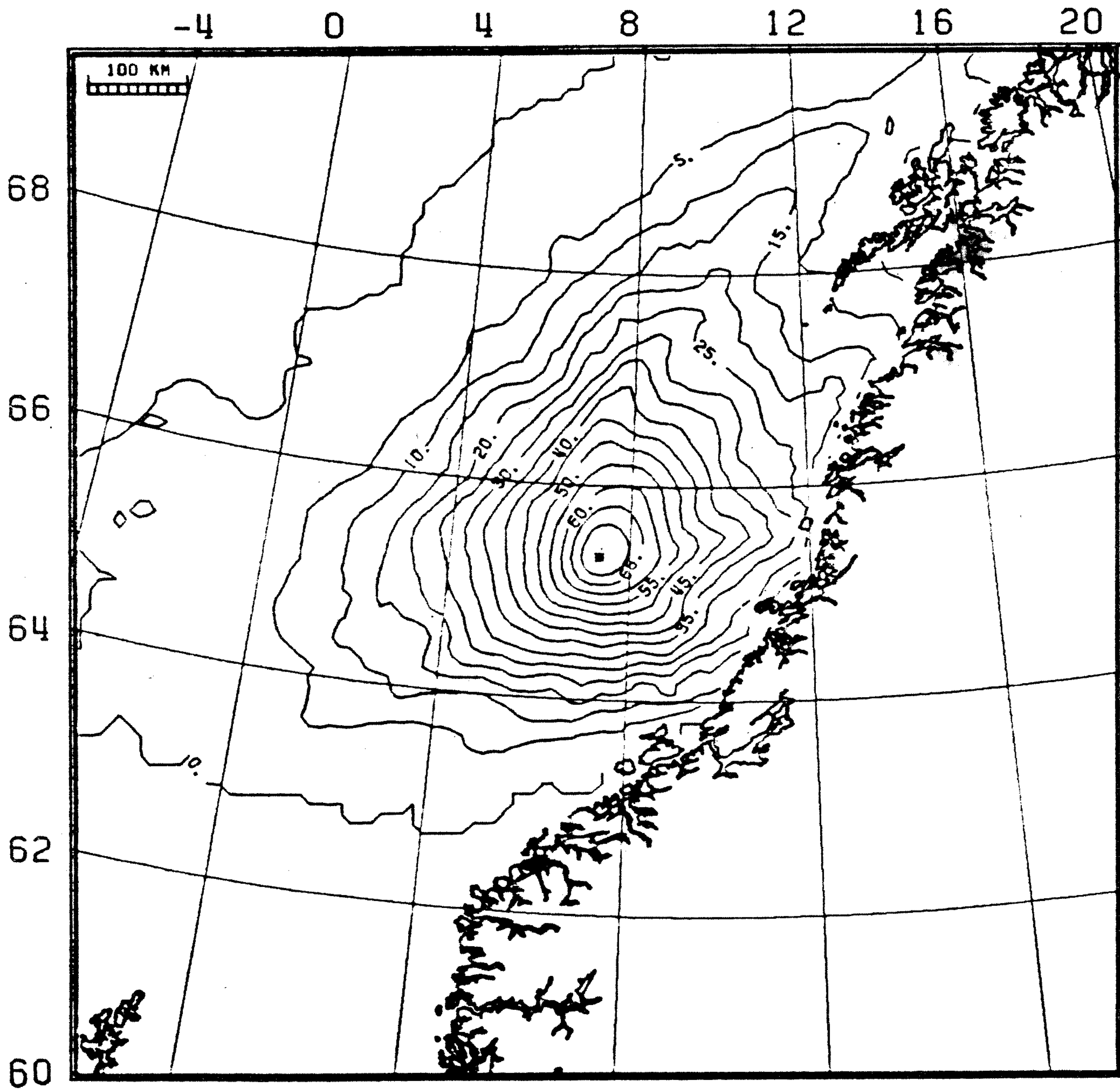
OIL SPILL POSITION:65°20'N 7°19'E
PERIOD : MAR,APR,MAY 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

MEAN DRIFT TIME
UNIT : DAYS



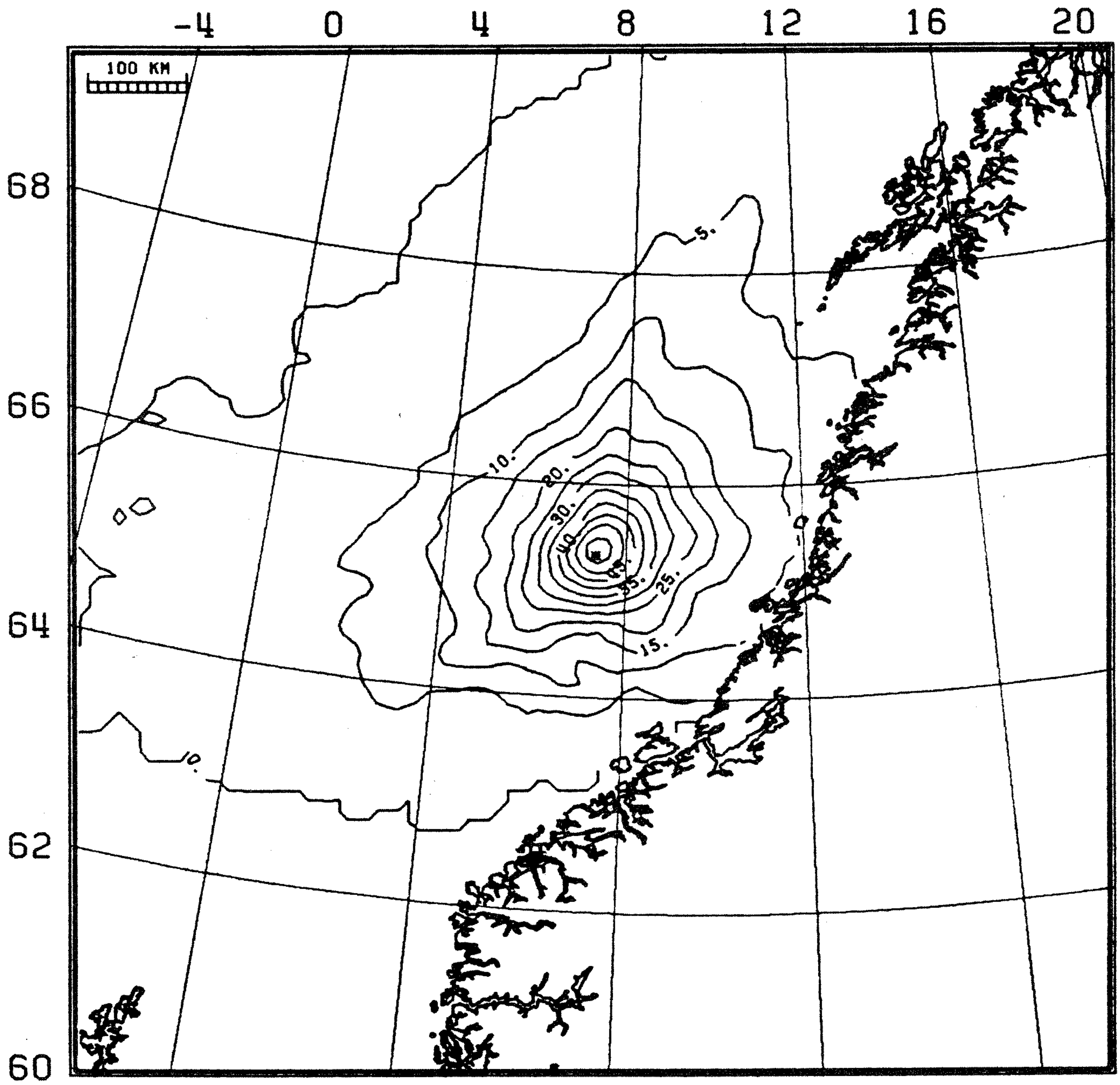
OIL SPILL POSITION: 65°20'N 7°19'E
PERIOD : MAR, APR, MAY 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

MAXIMUM AMOUNT OF OIL
UNIT : % OF SPILLAGE RATE



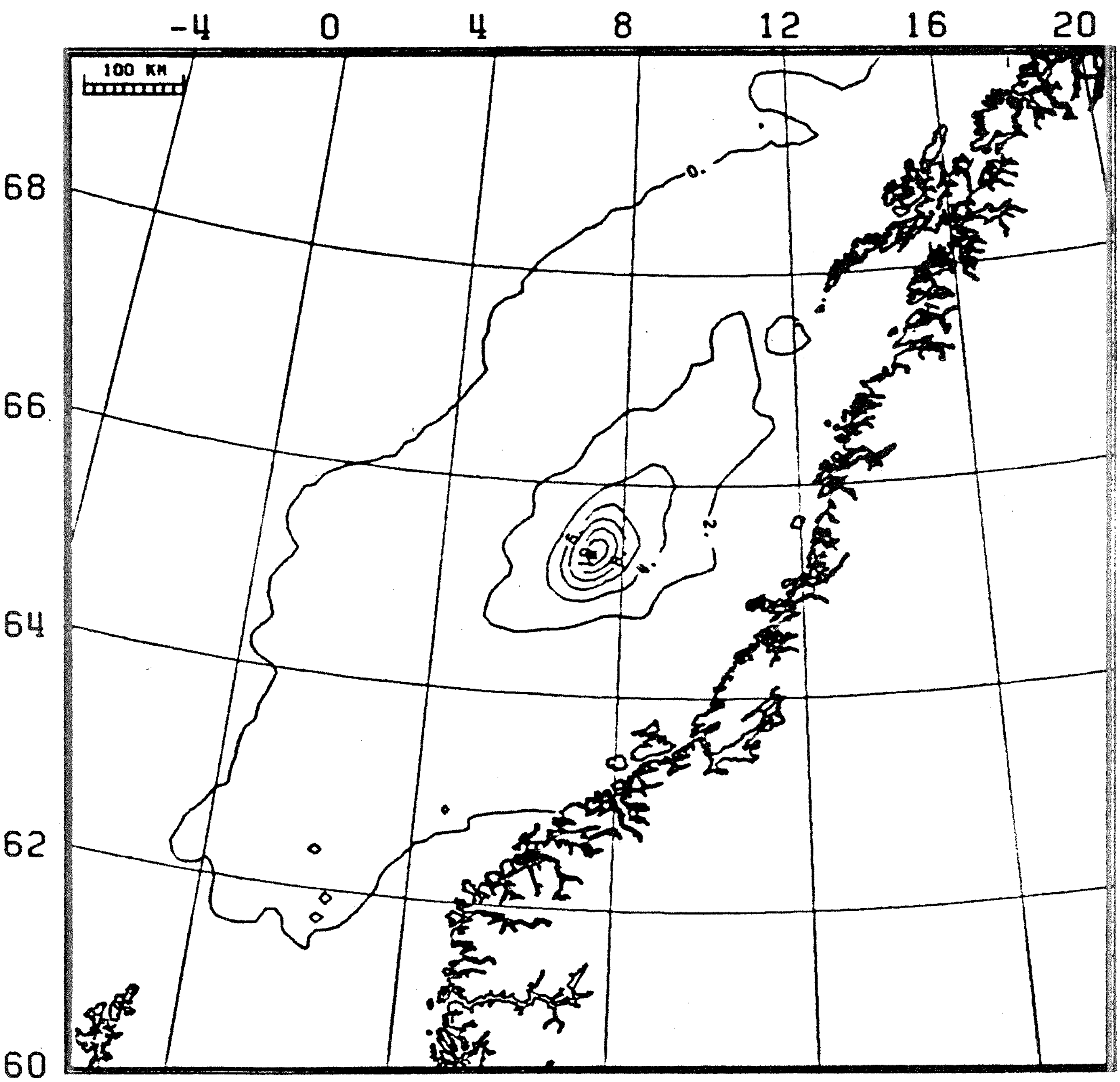
OIL SPILL POSITION:65°20'N 7°19'E
PERIOD : MAR,APR,MAY 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

MEAN AMOUNT OF OIL
UNIT : % OF SPILLAGE RATE



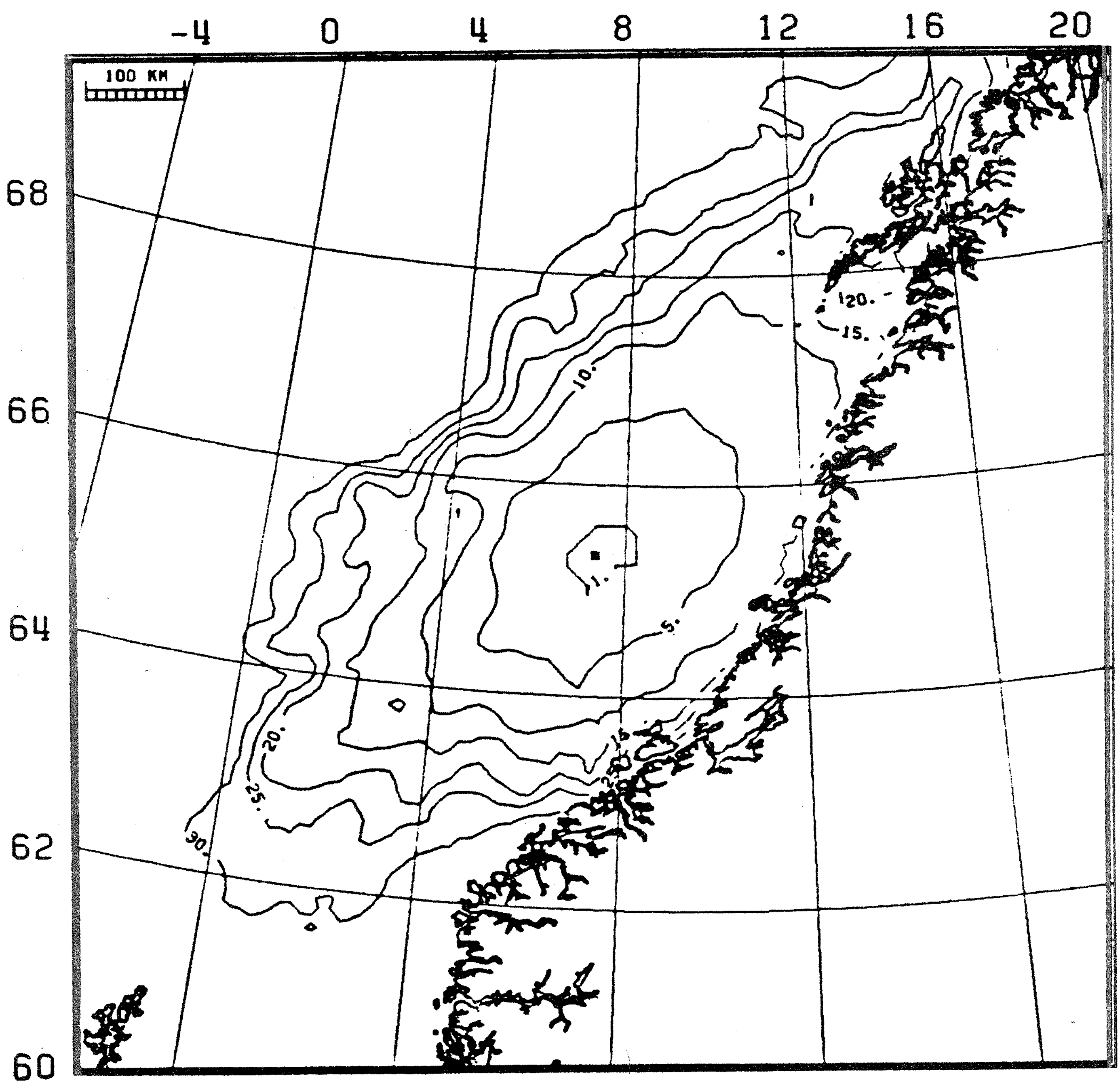
OIL SPILL POSITION: 65°20'N 7°19'E
PERIOD : JUN, JUL, AUG 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

ARRIVAL FREQUENCY PER. 10X10 KM AREA
UNIT: % OF TOTAL NUMBER OF SPILLS



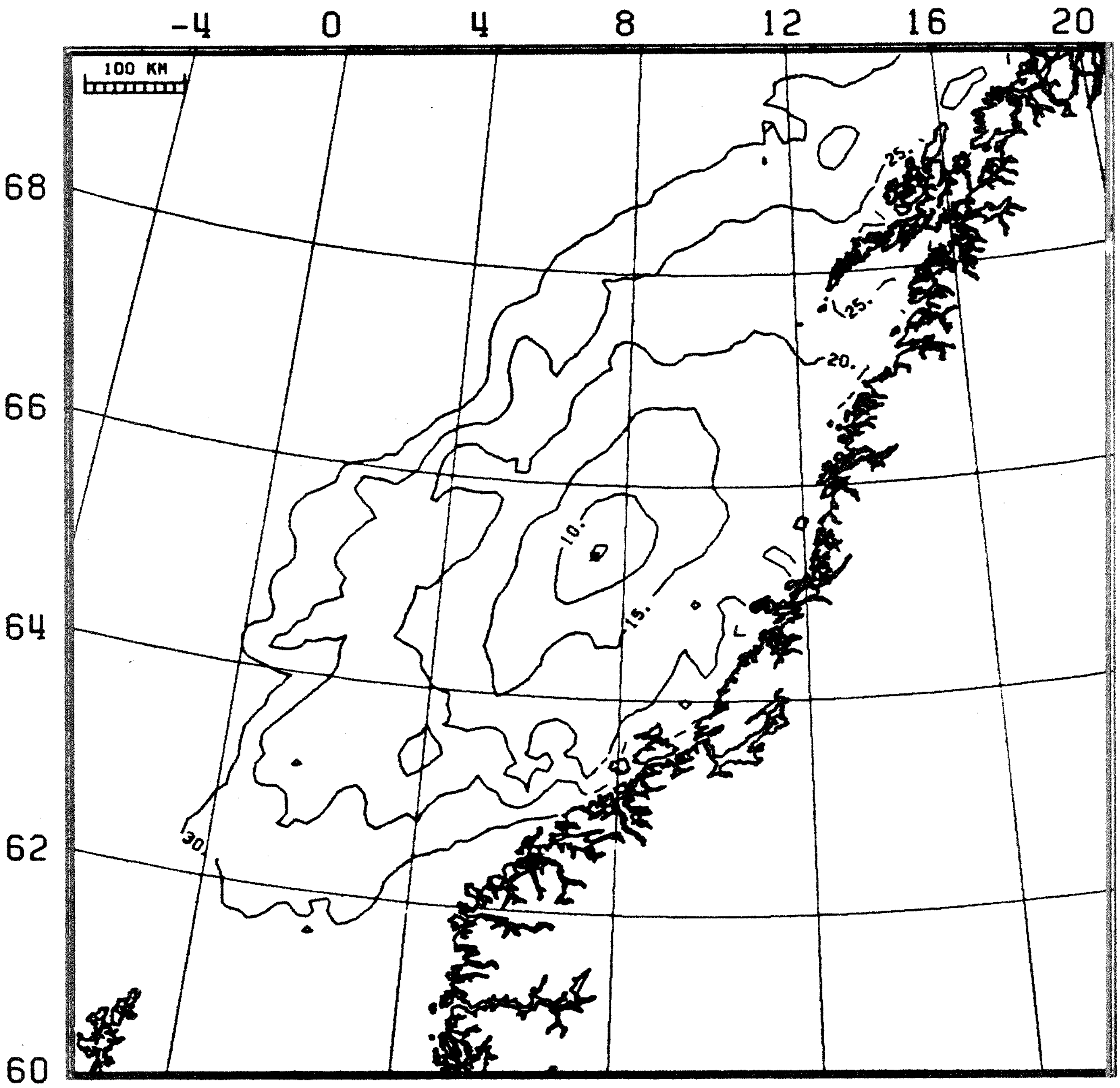
OIL SPILL POSITION: 65°20'N 7°19'E
PERIOD : JUN, JUL, AUG 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

MINIMUM DRIFT TIME
UNIT : DAYS



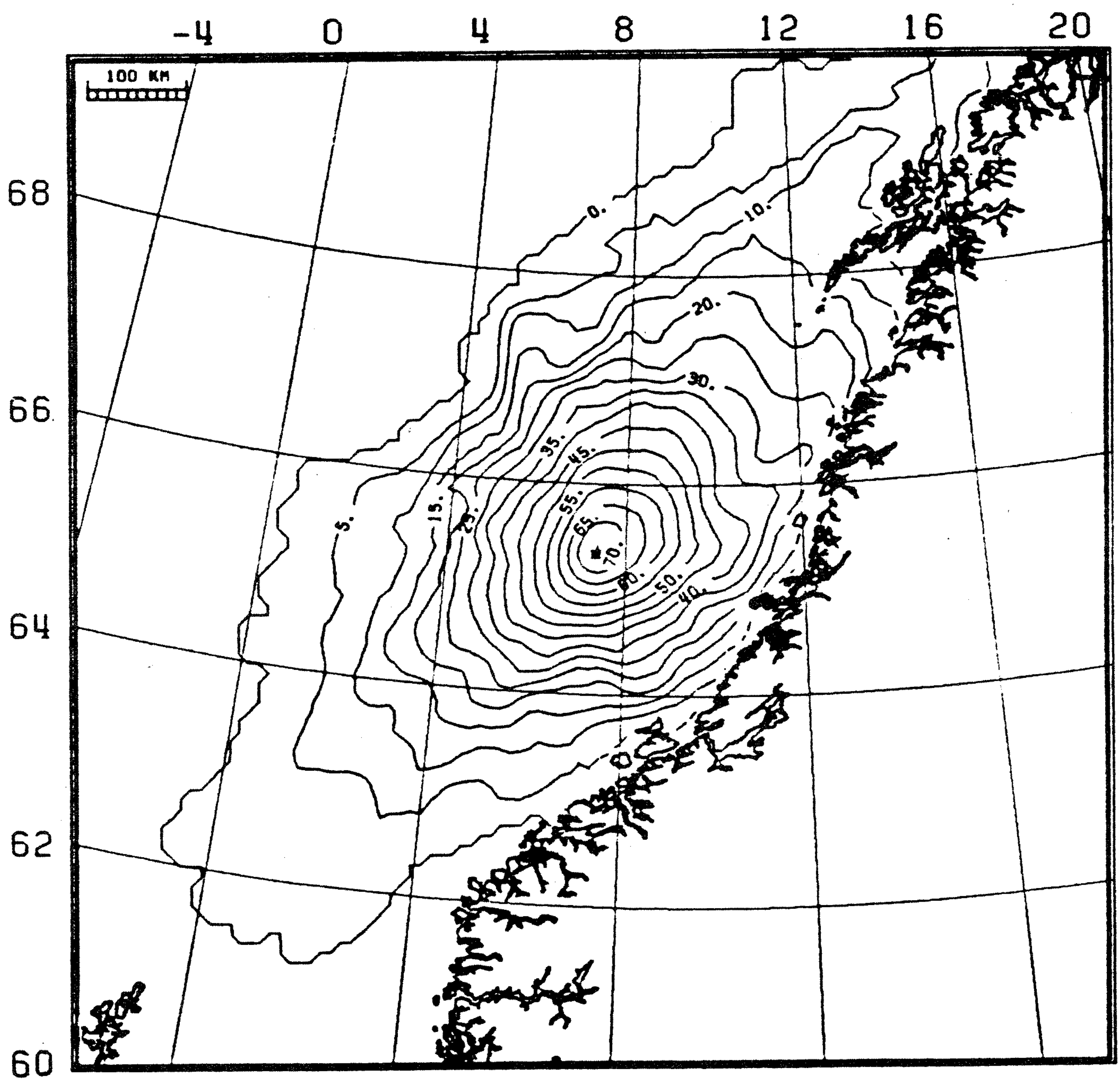
OIL SPILL POSITION:65°20'N 7°19'E
PERIOD : JUN,JUL,AUG 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

MEAN DRIFT TIME
UNIT : DAYS



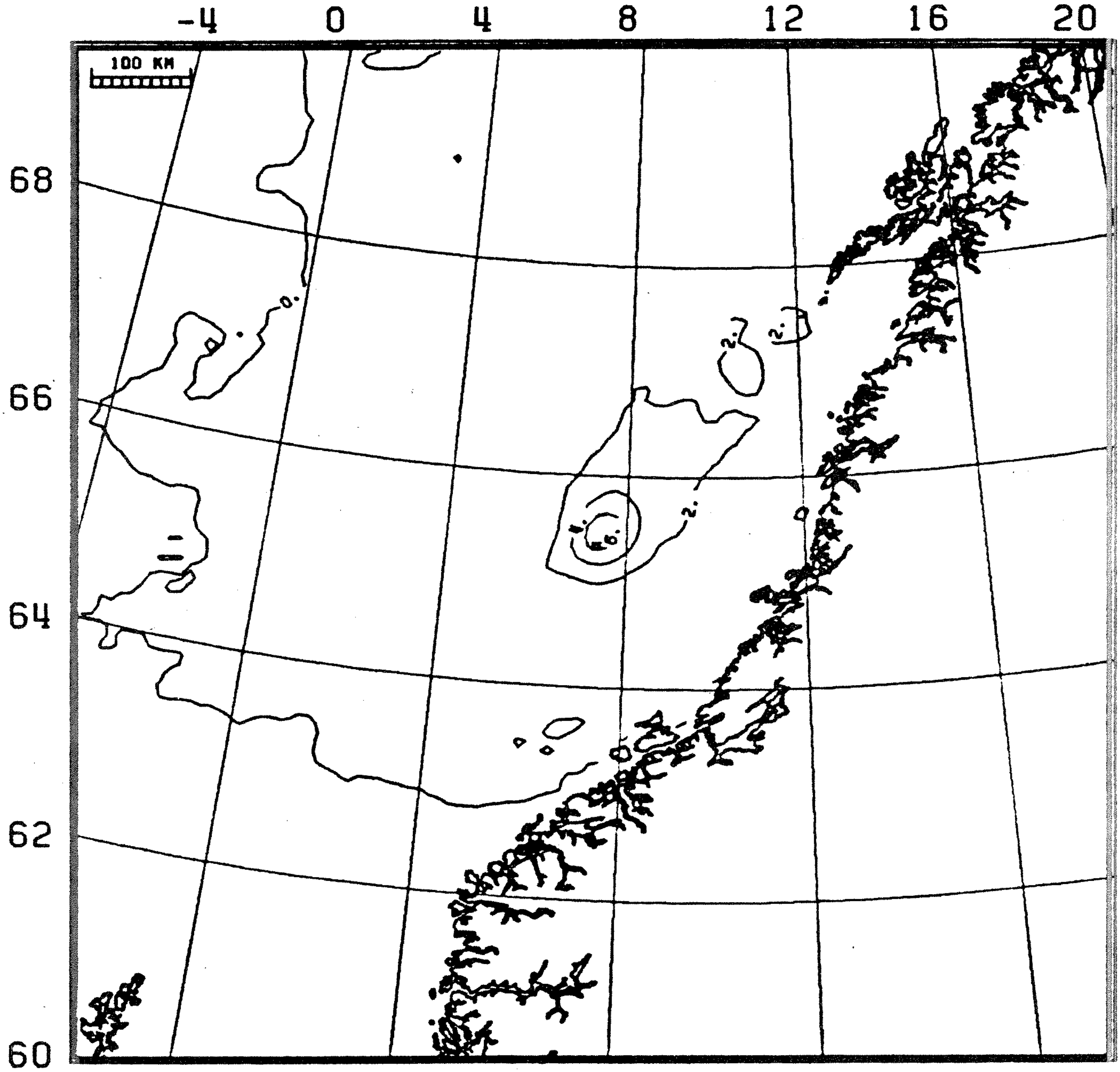
OIL SPILL POSITION: 65°20'N 7°19'E
PERIOD : JUN, JUL, AUG 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

MAXIMUM AMOUNT OF OIL
UNIT : % OF SPILLAGE RATE



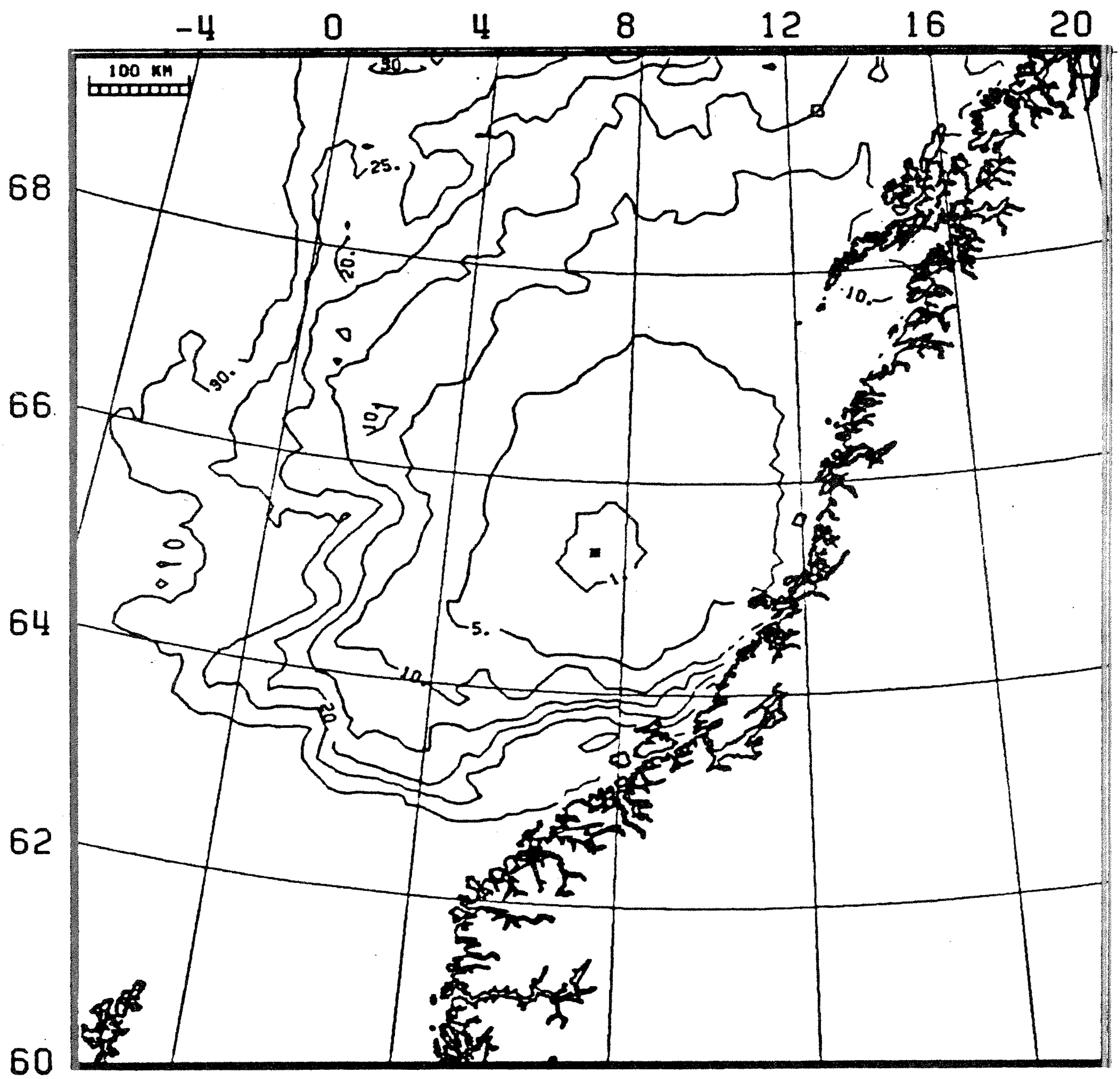
OIL SPILL POSITION: 65°20'N 7°19'E
PERIOD : SEP, OCT, NOV 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

ARRIVAL FREQUENCY PER. 10X10 KM AREA
UNIT: % OF TOTAL NUMBER OF SPILLS



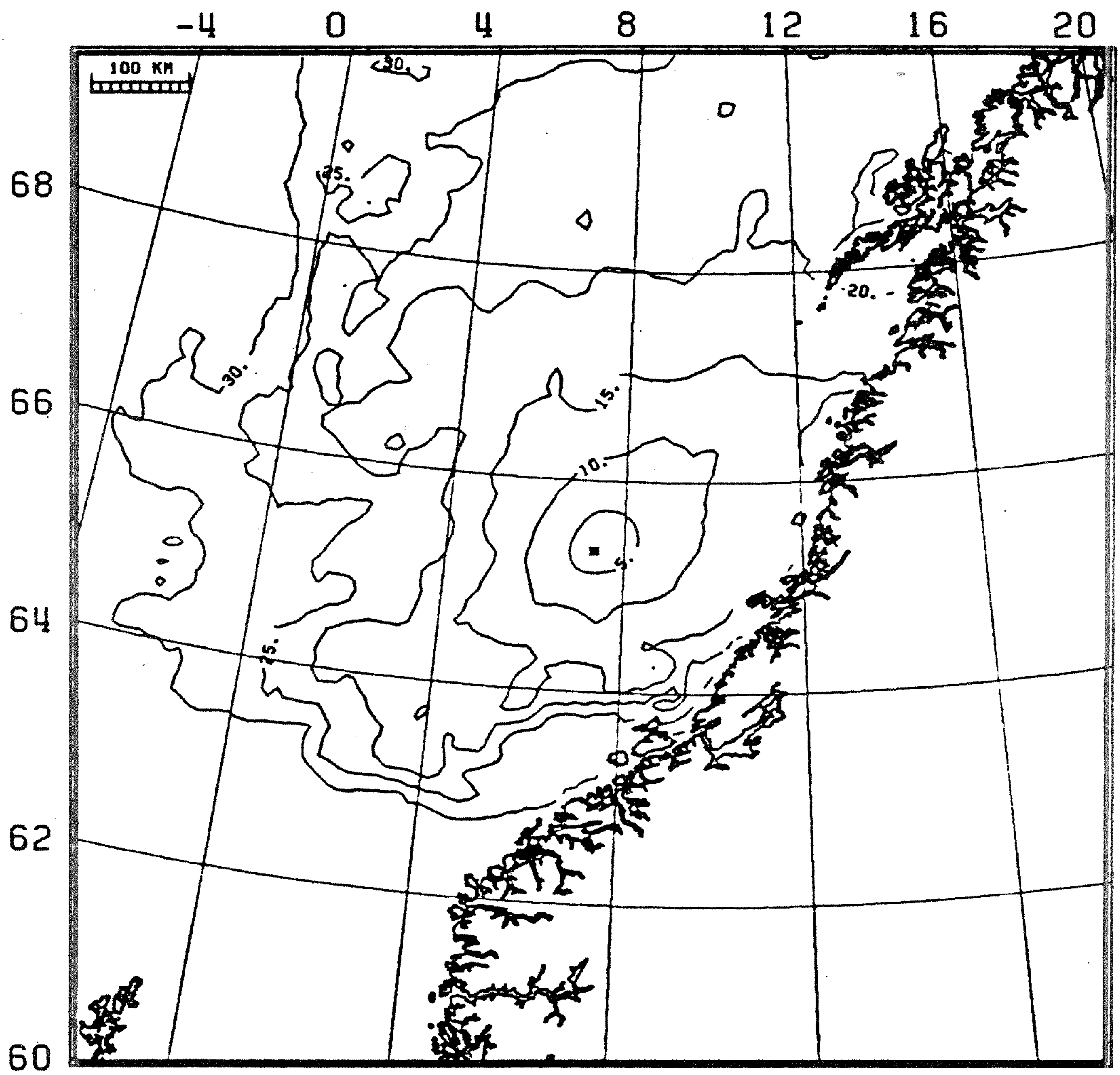
OIL SPILL POSITION:65°20'N 7°19'E
PERIOD : SEP,OCT,NOV 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

MINIMUM DRIFT TIME
UNIT : DAYS



OIL SPILL POSITION: 65°20'N 7°19'E
PERIOD : SEP, OCT, NOV 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

MEAN DRIFT TIME
UNIT : DAYS



OIL SPILL POSITION: 65°20'N 7°19'E
PERIOD : SEP, OCT, NOV 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
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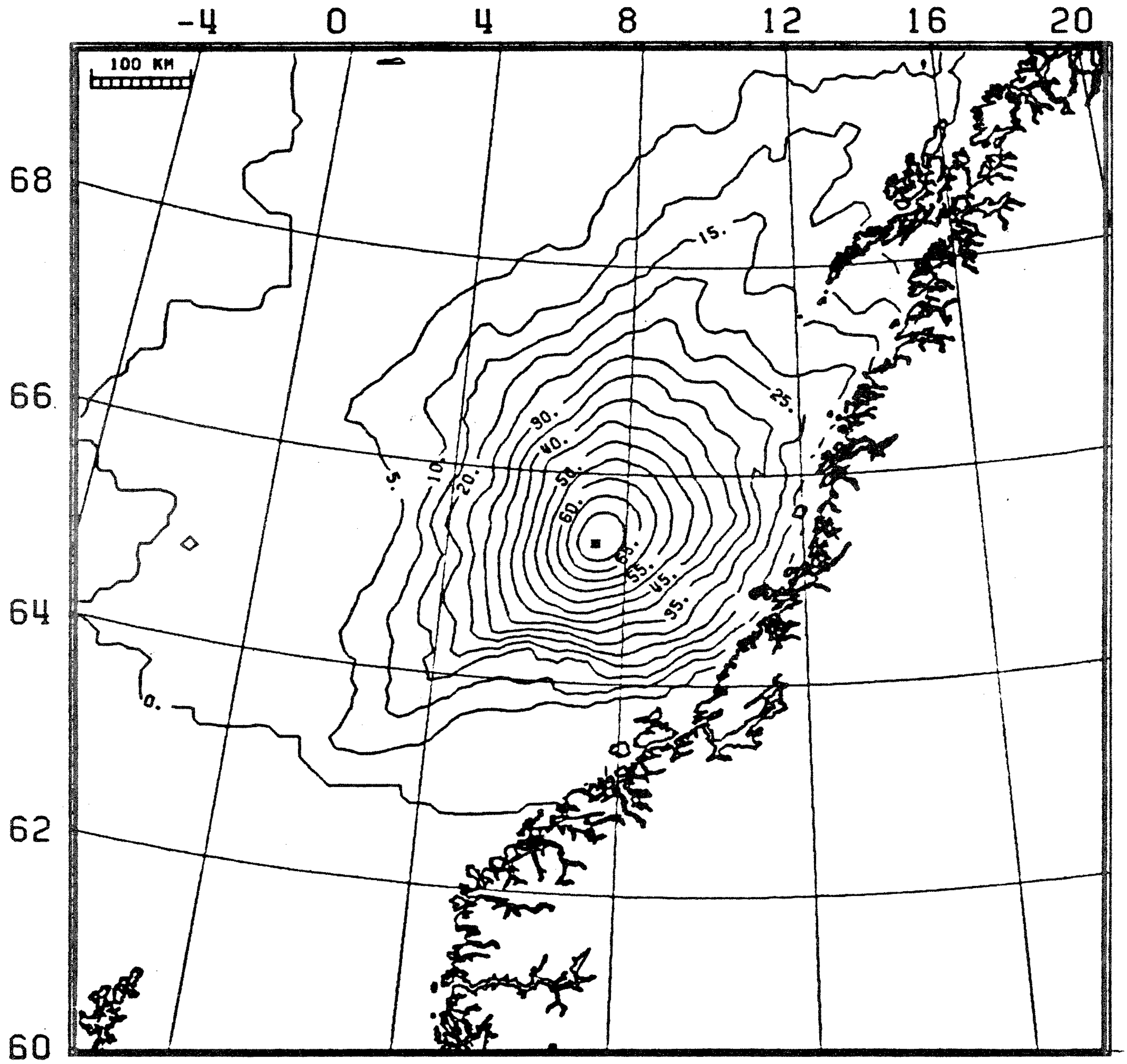
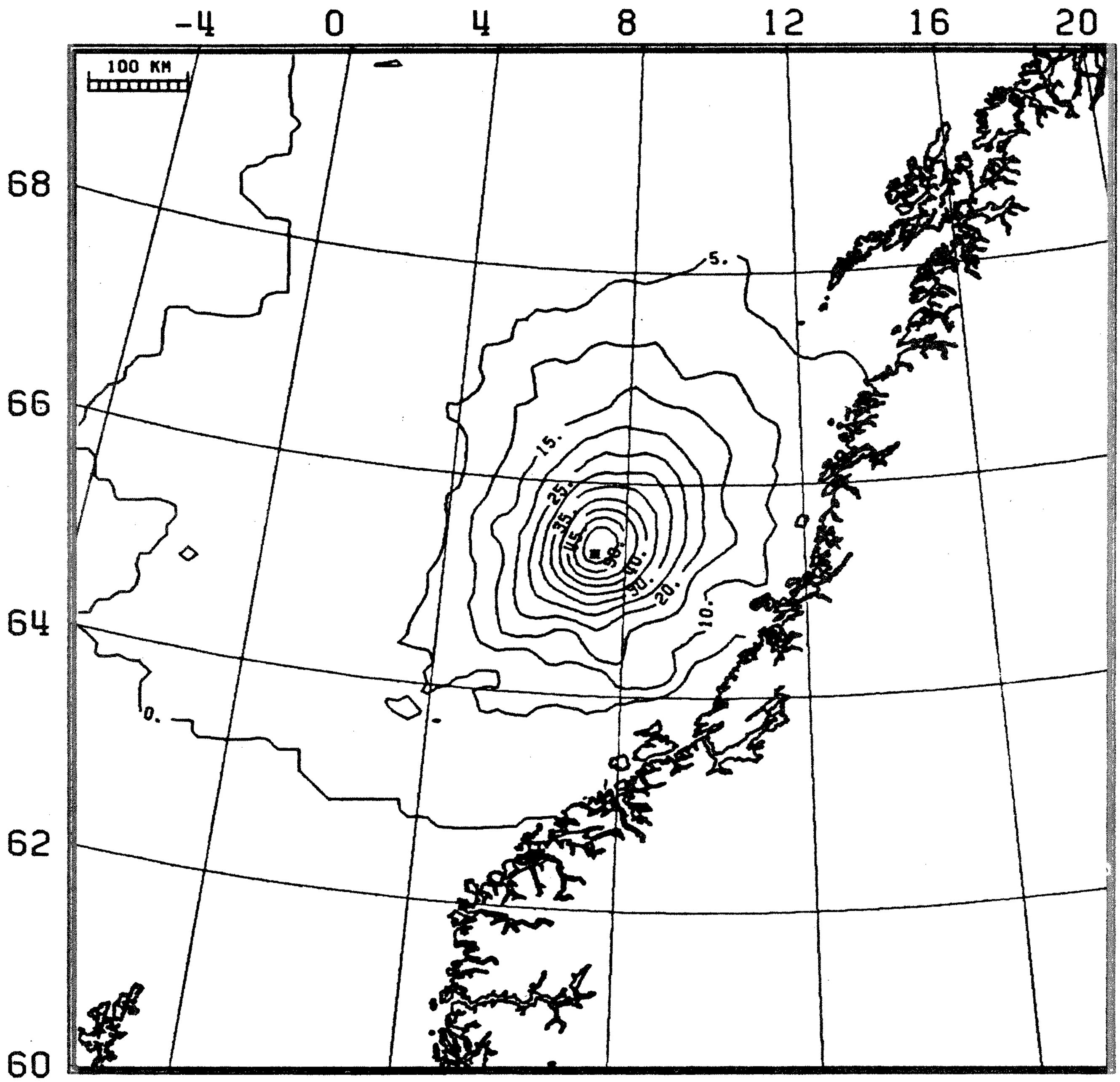
MAXIMUM AMOUNT OF OIL
UNIT : % OF SPILLAGE RATE



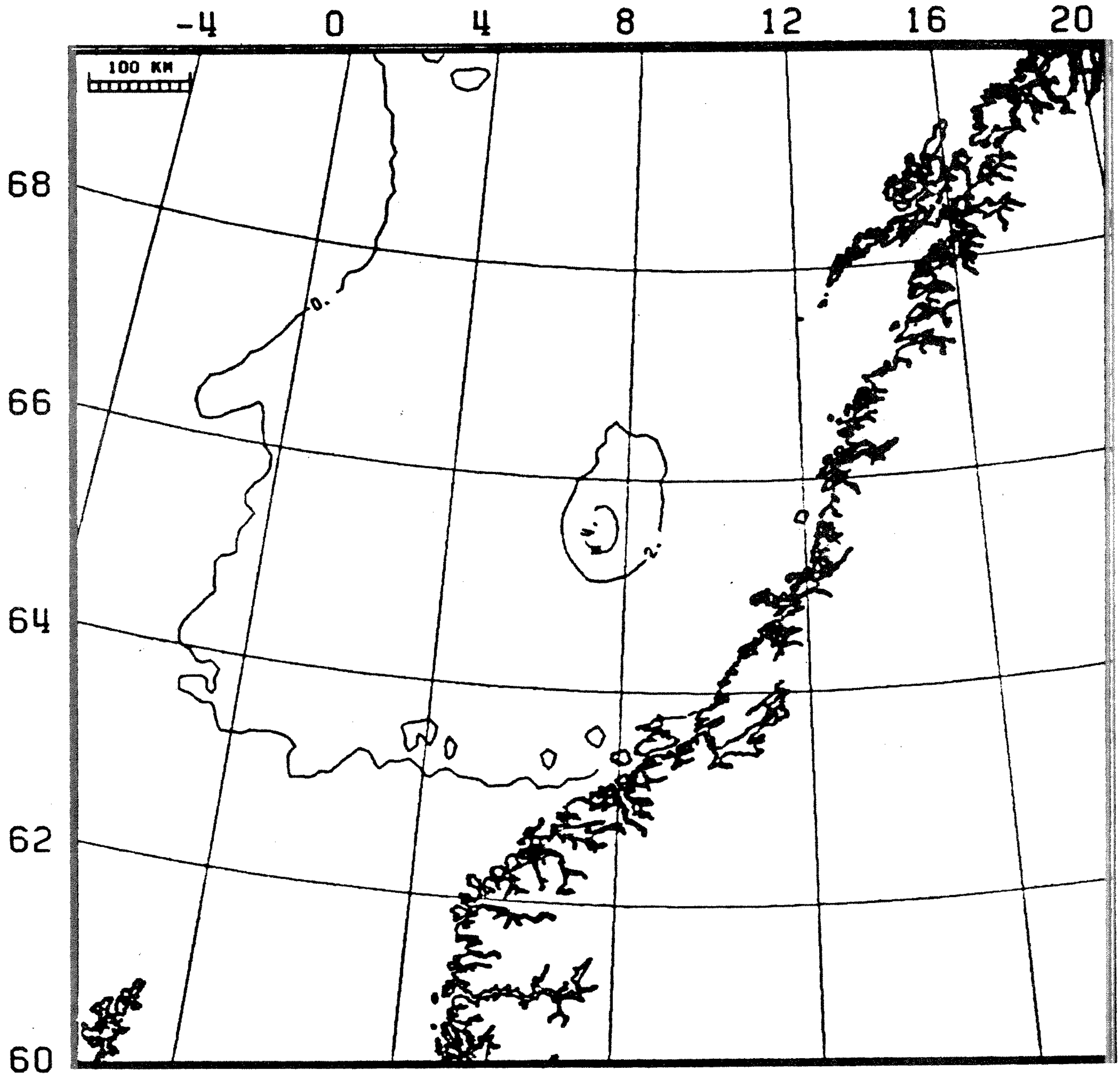
OIL SPILL POSITION: 65°20'N 7°19'E
PERIOD : SEP, OCT, NOV 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

MEAN AMOUNT OF OIL
UNIT : % OF SPILLAGE RATE



ØIL SPILL POSITION 65°20'N 7°19'E
PERIØD : DEC, JAN, FEB 1955-1981
SPILLAGE RATE: 120 TONN/HØUR
DENSITY : 900 KG/M**3

ARRIVAL FREQUENCY PER. 10X10 KM AREA
UNIT: % ØF TØTAL NUMBER ØF SPILLS



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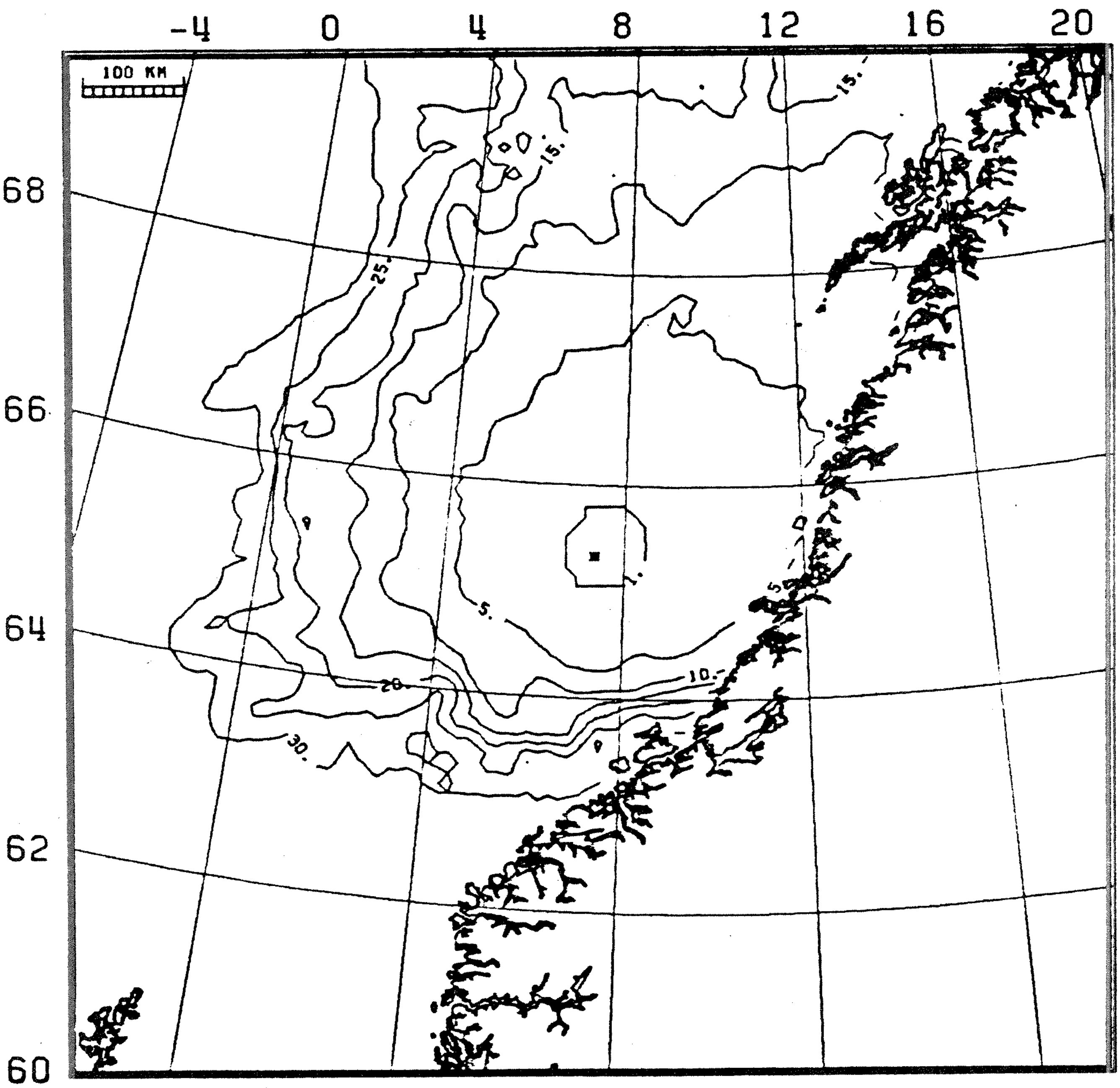
UNIT : DAYS



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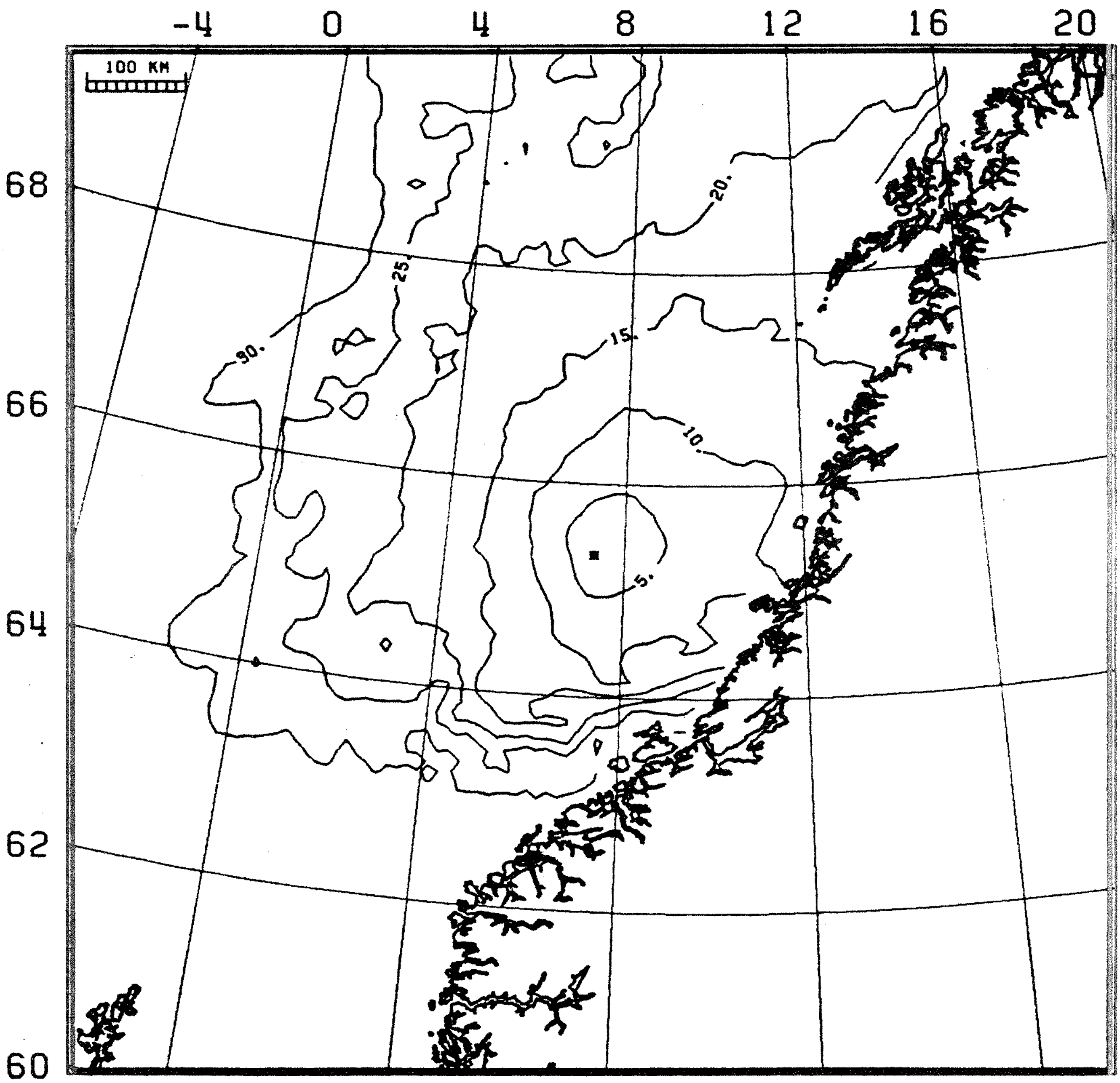
UNIT : DAYS



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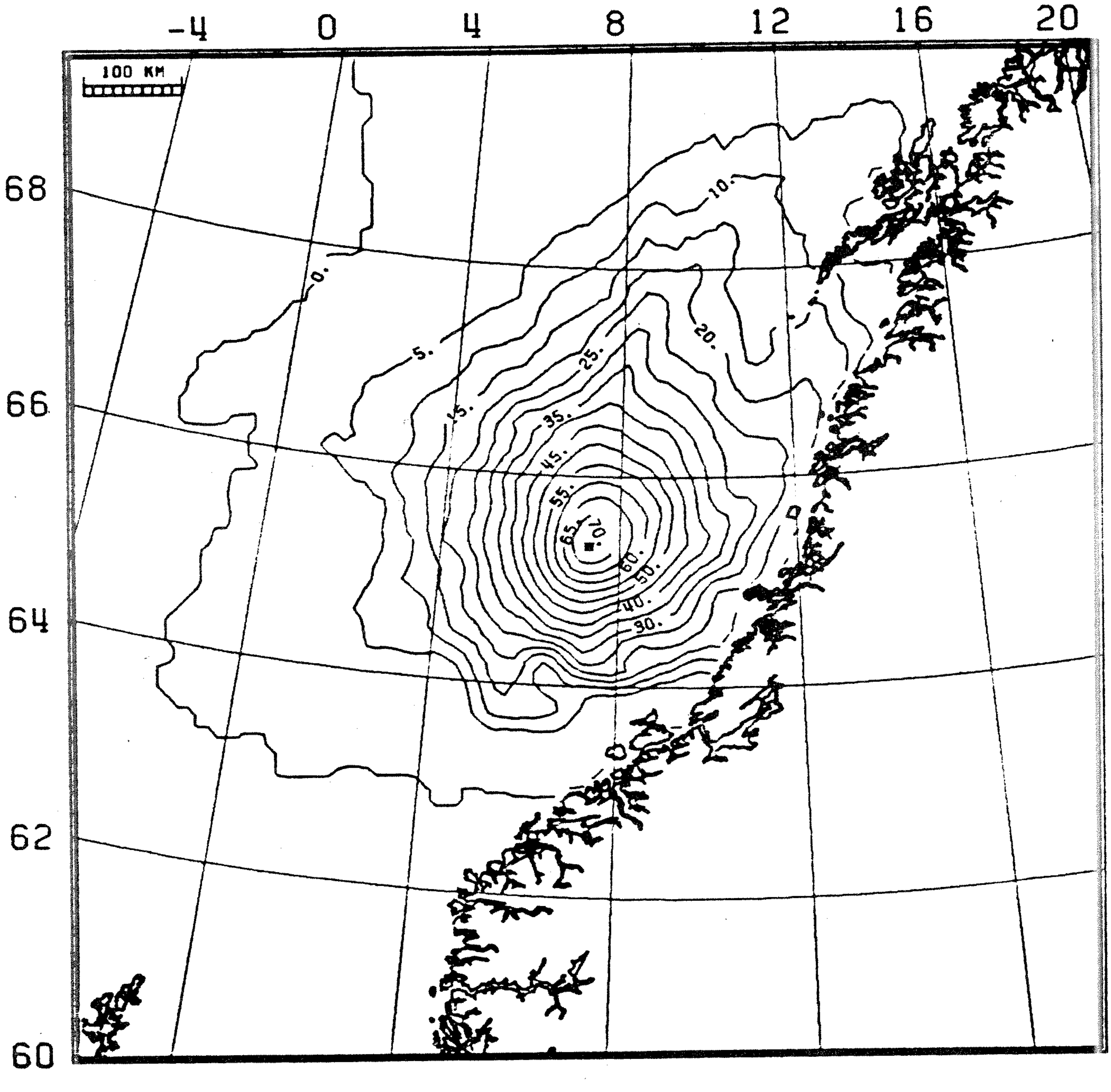
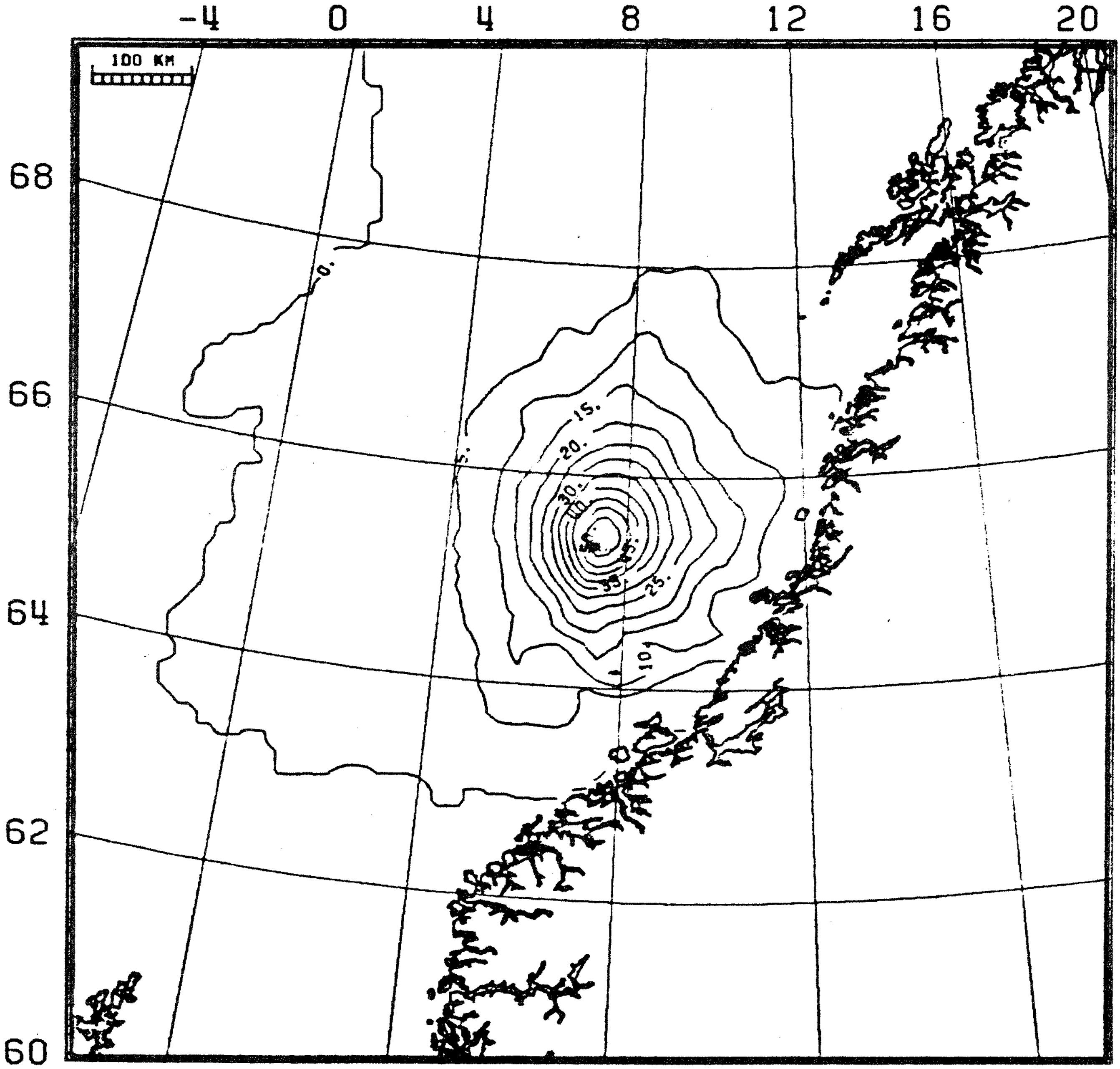
PERIOD : DEC, JAN, FEB 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

MAXIMUM AMOUNT OF OIL
UNIT : % OF SPILLAGE RATE



OIL SPILL POSITION:65°20'N 7°19'E
PERIOD : DEC,JAN,FEB 1955-1981
SPILLAGE RATE: 120 TONN/HOUR
DENSITY : 900 KG/M**3

MEAN AMOUNT OF OIL
UNIT : % OF SPILLAGE RATE



5. INSHORE AND SHORE ENVIRONMENT

5.1 GENERAL CONSIDERATIONS

5.1.1 Introduction

Chapter 5 aims to discuss the consquence of the Heidrun development on the coastal environment. We have defined this environment as the area stretching from the outer skerries and inwards to land as far up into the shoreline vegetation as an oil spill may be deposited during heavy weather. Subtidally we include water masses and bottoms as deep as we may expect significant amounts of oily material to be deposited. Normally this is regarded to be within the upper 20 meters of water, although resuspension of oily material from shallow water may bring hydrocarbons to deeper areas of fjords.

The report limits the assessment to the impact on the coast as an ecological system, and on activities linked to that. The repercussion of negative impact on the human society on the coast (e.g. economy, change in society structure) is beyond the scope of the report.

5.1.2 Sources of effects

The potential sources of effects and their relevance to coastal impact are:

A. Physical presence of platform and pipelines - losses of access to fishing grounds, artificial reef effects.

   No effect on coastline

B. Abandonment - physical presence of objects left on the sea floor.

   No effect on coastline

C. Anchoring of construction vessels and pipeline construction - seabed disturbance.

   No effect on coastline

D. Building of operation, supply and helicopter base.

   Physical disturbance likely in the vicinity: noise, traffic, dredging and deposition of mineral material.

E. Supply vessel traffic.

Disturbance due to waves and noise

F. Helicopter traffic.

Disturbance due to noise

G. Noise from drilling activities.

No effect on coastline

H. Cooling water discharge.

No effect on coastline

I. Blow-out followed by oil spill.

Severe effect on coastline

J. Rupture of submarine pipeline followed by a subsurface oilspill.

Severe effect on coastline

K. Discharge of drill cuttings and drilling mud.

Not likely to affect coastline

L. Oil in production and formation water.

Not likely to affect coastline

M. Additives in production and formation water, heavy metals, bicides, antioxidants etc.

Not likely to affect coastline

N. Sewage and other domestic wastes.

Not likely to affect coastline

O. Additives in water discharged after pipeline pressure testing.

Not likely to affect coastline

Normal platform discharges of produced water, ballast water, and sewage are not considered a threat, as they will be diluted to near background levels before possibly reaching the coast. Drill cuttings and used mud will settle out of the water in the vicinity of the Heidrun field, and it is not likely that resuspended cuttings material or chemicals leaching from the cuttings on the bottom will ever reach the coast. It may eventually be decided that drill cuttings and used mud will have to be shipped ashore (CONOCO information), but the possible consequences of this option is not to be treated in the present report.

The prime concern will therefore be to assess the probable consequences of oil drifting to the coast during or after an accident at the Heidrun field. We will also appraise the likelihood of effects from onshore base operation.

5.1.3 Changes in oil properties before a nearshore impact

Most of our experience with shoreline oil pollution incidents, and hence what we have to base our consideration of immediate acute effects on, relates to nearshore spills such as from tanker groundings or storage tank rupture. A major difference between such spills and oil drifting ashore from the Heidrun field will be the more pronounced weathering of the oil before the coast is reached in the latter case.

The rate of natural removal of oil from an area of the coast is less dependent on how long the oil has drifted before stranding. In this respect tanker accident experience is in general valid.

The physical and chemical alteration of a drifting oil with time is the sum of several weathering processes: spreading, evaporation, dispersion, dissolution, emulsification, sinking, photochemical and biological degradation. Mackay & al. (1983) have outlined procedures to predict the relative importance of these processes on basis of certain oil characteristics. The available information of the Heidrun field oil is insufficient to perform such analysis, but some general statements can be made on basis of Mackay & al. (1983).

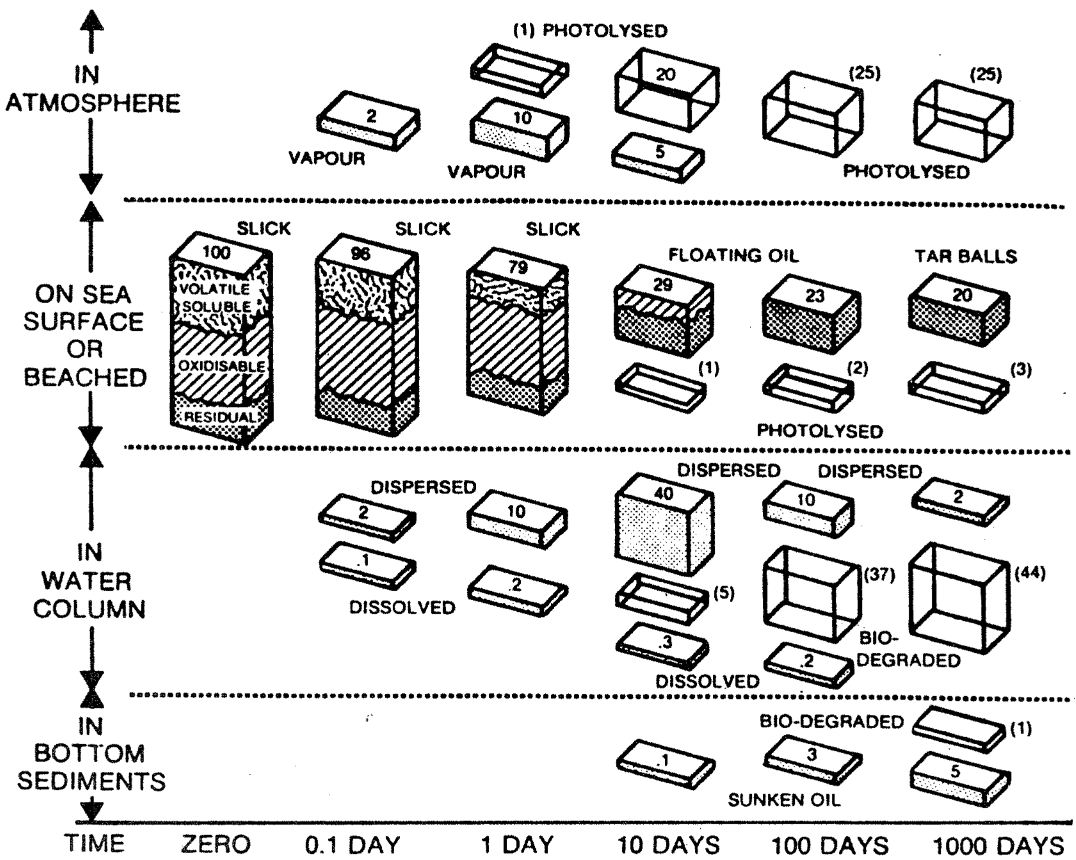


Figure 5.1.1. A speculative mass balance for a 'typical' oil spill. Redrawn from Mackay (1985).

Evaporation of the lighter components of the oil will start immediately and most of these will be lost in less than 10 days, depending on wind and temperature. In an average crude oil these compounds represent somewhat around 25% of the original oil (Figure 5.1.1). Dispersion and dissolution will also act from the moment of the spill. Macay & al. (1983) claims that all alkanes lighter than C_8, all monoaromatics, naphtalenes, and some three-ring aromatics (phenanthrenes) will dissolve if they are not evaporated, leaving on an average about 30 % of the original oil in contact with the surface. This residue will be subjected to emulsification, a process which also predominantly occurs during the first week.

The ability of crude oils to form stable water-in-oil emulsions (mousse) varies, but Mackay & al. (1983) claim that the most stable emulsions tend to involve both high asphaltene and wax content. The data available for samples of the Heidrun field oil (Data from Core Laboratories Norsk, courtesy of CONOCO NORWAY INC.) show that the content of these elements is low compared to a range of other crude oils (Data from unpublished factual summary report on the Claymore Pipeline Oil Spill Incident. Courtesy of CONOCO NORWAY INC.). The tendency for this oil to form a mousse should therefore be low compared to other crude oils, and the tendency for dispersal in the water column in rough weather likewise higher. This is considered an advantage with respect to shoreline pollution as more of the oil will be transported down into the water masses and reduce the surface slick.

The most likely chemical alteration of an oil slick is through photo-oxidation. This term covers a range of complex and vaguely understood chemical reactions primarily involving higher molecular weight compounds (e.g., resins, asphaltenes), molecular oxygen and light energy (Tjessem and Aaberg 1983). The products of photo-oxidation are reactive and generally considered more toxic than the parent hydrocarbon (e.g., Larson & al. 1977). Although the process is immediate if light is present (Tjessem & Palmork 1983), and may be very intense in oil sheens, there is no evidence that the rate is large enough to produce significant concentration of toxic components under an oil slick at drift. The oxidation products are however polar and may enhance the emulsification of the residue oil (Tjessem and Palmork 1983).

The processes listed above would in most cases lead to an oil reaching the coast which is more emulsified than in a tanker accident, and which certainly has lost more of the lighter and toxic components to the water and air during drifting. Tanker accident experience can therefore be regarded as representing a "worst case" situation encountered when wind and currents transport the oil ashore within a few days i.e., in less than a week, giving a combined effect of smothering and chemical toxicity. In our consideration we have assumed that an oil slick hitting the shore in less than 5 days will still contain significant amounts of compounds toxic to the biota.

After longer drifting time the most likely immediate impact on the coastline is smothering rather than chemical toxicity. We expect that oil older than 10 days will act through smothering alone. Such impact is most likely to affect coastal surface activities (fishing, fishfarming, boating, amenities), birds, mammals, and ecological communities in the tidal zone and above this, and with less effects on the subtidal system.

5.1.4 Coastal area of possible impact

Based on the oil spill modelling (chapter 4) and the options given for locations of the supply and helicopter bases (chapter 2) the total coastal area which in one way or the other may be impacted stretches north-east from Ona in the county of Møre og Romsdal to north of Senja in the county of Troms (the spill model maps do not extend north of Senja). This is an extremely complicated coastline with a length of 8700 km on the mainland. In addition it is bordered by thousands of islands and skerries, and is broken up by numerous fjords, some of which are among the largest in Norway. This gives a potentially impacted coastline of 27 000 km, i.e. a length equivalent to about 75% of the circumference of the earth!

The sea along this coastline is highly productive, and forms the basis of a living for large colonies of sea birds, and populations of mammals such as seals, mink and otter, as well as whales. This production is also exploited by man through important local and regional fisheries, aquaculture, harvesting of kelp etc. and these activities forms the basis for the human settlement along major parts of the coastline. Furthermore, the coast is highly valued both nationally and internationally as a tourist and recreational resort, and contains numerous regions which are defined as nature reserves or considered to be protected.

Basically the whole of the coast should therefore be considered as sensitive to oil spill impact. It is, however, apparent that the oil spill combat equipment available will only cover small areas of the coast in the event of a spill. The objective of the present assessment is, therefore, to single out those regions, areas, biotopes, and seasons where an oil spill is most likely to occur, and where the damage is likely to be most severe, and therefore are most pertinent to protect against a spill. These should be given priority before those which are either less "valuable", or where the impact is considered to be small or short term. Underlying the considerations given in the following chapters is therefore a 3 step priority among the objects in question:

1. High value and sensitivity
2. Medium value, high or low sensitivity
3. Low value or low sensitivity

The weighting between value and sensitivity will be different for the different chapters. For simplicity the assessment is done for each county separately.

We have not made an overall priority assessment across the elements treated in chapters 5.3 to 5.9 since it must be considered a political task to decide which is most important to protect in the event of a spill, e.g., a high priority fish farming area or a high priority seabird nesting place. We have, however, tried to make an overall identification of the most vulnerable stretches of the coast in Chapter 6.

The maximum extent of coastline that may receive oil from a spill according to the drift simulations in Chapter 4 is from Fræna in Møre og Romsdal to north of Senja in Troms. The spill simulation maps do not extend north of Senja. On basis of the postulated mean amounts of oil hitting the coast we have divided the coastline into impact zones.

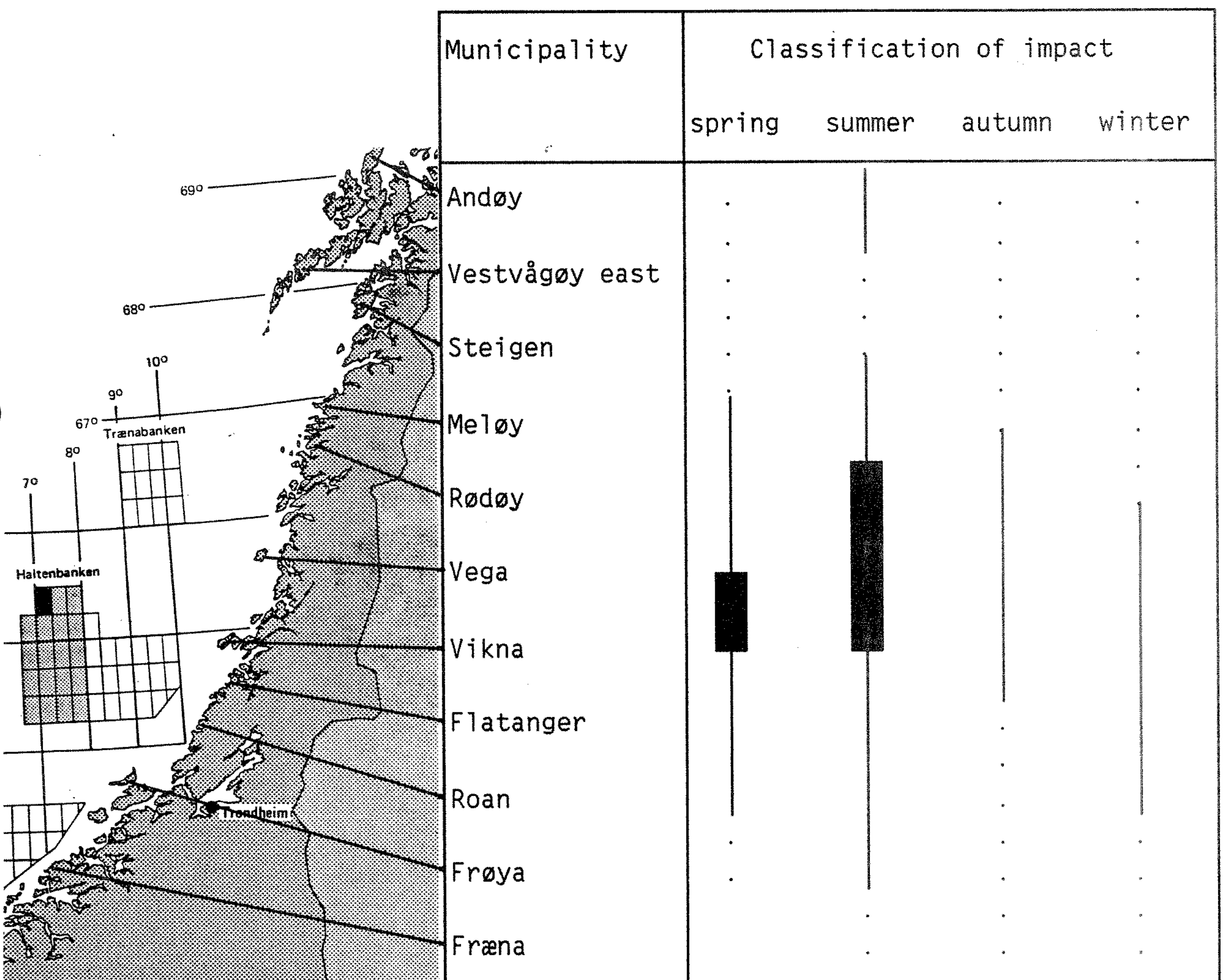
A high impact zone is defined as the part of the coast which in any season will receive oil at a mean rate which is 10% or more of the rate of oil discharged at Heidrun during an accident. The drift modelling suggests that no part of the coast will receive oil at a mean rate of more than 15% of the rate of oil discharged. Coastlines receiving between 5 and 10% of the discharge rate in any season are defined as medium impact zones. Those coastlines receiving between 0 and 5% of the discharge rate are classified as low impact zones. Table 5.1.1 shows the classification of the areas of the coast at different seasons throughout the year.

On basis of the drift model the coastline from Meløy to Vikna must be classified as the high impact zone, where it is likely that oil will enter the coastal ecosystem at a rate of more than 10% of the spill discharge rate during summer. During spring the a somewhat shorter coastline: from Vikna to Vega will be similarly impacted. In autumn and winter it is not likely that any section of the coast will be in what is classified as an high impact zone.

The medium impacted zone will have its greatest extension in summer: from Frøya to Vikna, and from Meløy to Andenes, with the exception of the inner part of Vestfjorden (The coast from Steigen to the east side of Vestvågøy). which is always in the low impact zone. In spring the medium zone goes from Roan to Vikna and from Vega to Meløy. In autumn the medium zone goes from Vikna to Meløy, and in winter this is shifted slightly south from Roan to Rødøy.

One should stress at this point that these considerations are based predictions of an average oil spill behaviour, and that the impact zones in Table 5.1.1 merely give an indication of the average vulnerability of the various sections of the coast to a range of oil spill scenarios. In general one may state that the region most likely to be hit by an oil spill from Heidrun at any time of the year is from Vikna to Meløy.

Table 5.1.1 Classification of the various sections of the coastline into high, medium and low impact zones with respect to the mean rates of oil coming ashore. The classification is based on the oil spill modelling in Chapter 4. Broad line: high impact; thin line: medium impact, dotted line: low impact



5.1.5 Drifting time from Heidrun to the coast

The fastest predicted drifting time from the Heidrun field to the coast can also be inferred from the model in Chapter 4. The shortest time the oil will take to reach the coast in the high impact zone will generally be between 5 and 10 days. In summer the oil will take 10 days or more to reach the coast. In winter the western part of the islands of Vikna and Vega may receive oil in less than 5 days. These regions are therefore the only part of the coastline where the oil is still likely to be chemically toxic.

In the medium impacted region from Andøy to Meløy drifting time will in general lie between 5 and 15 days except in summer when shortest time may be 10-20 days.

In the medium region from Frøya to Folda drifting time will be slightly above 5 days in winter and spring, but in the souternmost part of the region oil will take 20-30 days or more to reach the shore.

5.1.6 Amounts of oil on the coast

On basis of data in Chapter 4 we have attempted to give a rough estimate of the maximum amount of oil which may hit the impact zones in the two spill scenarios described in Chapter 2. A worst case drift situation with all the oil following the main drift trajectories leading towards the coast, will probably give an overestimation of the amounts stranded during spills of long duration, since persistent strong wind in one direction is likely to last no more than 2-4 days (DNMI, Martinsen, pers. inf.). We have therefore assumed a worst case situation with onshore wind for half of the time oil is discharged, i.e. that half of the amount discharged will be driven towards the coast. Furthermore, one should keep in mind when looking at the calculated amounts, that the calculations are based on the isoline maps for mean amounts of oil in Chapter 4. The chapter stresses that the real amounts of oil will be somewhat less than the isolines indicate, and more so as drifting time increases.

Oil drifting ashore in the high impact zone will have lost between 85 and 90% of its original weight. Assuming a single well blowout of 10 days duration with a discharge of 20 000 barrels/day (= 2 900 tonnes/day) a maximum of 1 500 - 2 200 tonnes of oil will drift ashore in these regions. In a worst case situation of a multi-well blowout with a discharge of 100 000 barrels a day in 120 days (= 14 500 tonnes/day), these areas would receive a maximum of 172 000 - 258 000 tonnes of oil.

The medium impacted zones will receive oil at a rate of 5-10% of the discharge rate (90-95% lost on the way). In the two scenarios these sones may be hit by a total of at the most 750 - 1 500 tonnes and 86 000 - 172 000 tonnes of oil.

The low impact coastline will on an average receive less than 5% of the daily discharge per unit time. This means that more than 95% of the discharge is lost to the air and water before the oil hits the coast. The low impact coast may therefore receive up to 750 and 86 000 tonnes of oil in the two scenarios respectively.

Table 5.1.1. Magnitude of oil spills in offshore and coastal regions (from various sources) in comparison to the worst case spill scenarios on the impact coast from Heidrun.

Incident	Year	Location	Amount of oil (tonnes) discharged		stranded
Torrey Canyon	1967	Cornwall UK	18 000	~	14 000
Florida	1969	Mass. USA	630	~	630
Arrow	1970	Nova scotia	11 000	~	11 000
Metula	1974	St. of Magellan	50 000	~	35 000
Argo Merchant	1976	offshore Atlantic	15 000		0
Bravo	1977	North Sea	20 000		0
Tsesis	1977	Baltic Sea	1 100		?
Amoco Cadiz	1978	Brittany	230 000	~	65 000
Ixtoc I	1979	Mexico	1.6 -0.4 mill	~	10 000[1]
Dei Fovos	1981	Helgeland	1 000	~	1 000
Heidrun	-				
scenario 1	-				
high	-	Helgeland	29 000		1 500 - 2 200
medium	-	North Norw.	29 000		750 - 1 500
low	-	North Norw.	29 000		0 - 750
scenario 2	-				
high	-	Helgeland	1.7 mill		172 000 - 258 000
medium	-	North Norw.	1.7 mill		86 000 - 172 000
low	-	North Norw.	1.7 mill		0 - 86 000

[1] Estimated stranded on the coast of Texas.

These estimates give a rough impression of the magnitude of likely worst case oil volumes that may drift ashore from the Heidrun field. In Table 5.1.2 they are compared with some of the more well known spill accidents that have happened during the last 20 years. The comparison gives a useful perspective of the likely severeness of an accident at the Heidrun field, but cannot be used to postulate anything of the shoreline consequences.

The table shows that the worst case of a single spill scenario will cause shoreline pollution far less than most of the major tanker accidents, and in fact of the same magnitude as the "Dei Fovos" spill. On the other hand the worst case of a blow out scenario may cause far more oil stranded than hitherto recorded in any spill. Even the medium impacted zone may then receive as much oil or more as the coast during the "Amoco Cadiz" accident where the shores of Brittany in France in 14 days received about 65 000 tonnes of light crude oil over a 250 km distance of the coast (Beslier & al. 1980). A blowout of the magnitude suggested could therefore in the worst case lead to a coastal oil pollution incident more severe than any hitherto recorded spill.

5.2 SHORE TYPE AND SEDIMENT CHARACTERISTICS

5.2.1 Objectives

The primary aim of this chapter is:

(i) to give a generalized classification of shores and shoreline sediments,

(ii) to evaluate possible impact on the shore/sediment types from a production accident,

(iii) to outline the selfcleaning ability for oil,

(iv) to localize vulnerable shores on the coastline in question.

5.2.2 Generalized shore/sediment classification.

The shore/sediment type that is to be found is determined by the energy regime at the location in question. Different operational classification of substrates may be used. According to Håkanson (1981) one meaningful way is to classify according to particle fate:

(i) depositional substrates. These areas act as a sink for particles with diameter down to less than 0.006 mm.

(ii) transport substrates. These comprise areas where the fines will be deposited discontinuously.

(iii) erosion substrates. These are sites where fine sediment particles will not be deposited.

These three main cathegories could be further subdivided. However, that is more pertinent when evaluating the possible impact on the ecological communities of the shoreline.

The first category will include muddy, clayey and silty substrates where the main sedimentary processes are sedimentation and deposition. Sandy substrates will be addressed as transport bottoms characterized by both deposition and erosion depending on the current wave situation. Purely erosion substrates include rocky headlands, and bottoms consisting of boulders, stones and coarse gravel.

5.2.3 Sources of information

The distribution of the shore types on the coast in question is mainly based on the senstivity maps produced by SINTEF for the counties of Nordland (Klokk & al. 1984), Nord-Trøndelag (Hoddø & al. 1984), and Sør-Trøndelag (Tømmerås & al. 1985). These maps cover most of the coastline, but do not contain information on some of the fjords. Additional information on shore conditions in Glomfjord, Vefsenfjord and Ranafjord has been sought from NIVA-reports (Haugen & al. 1981, Knutzen 1984, Molvær & al. 1984). Information on the inner part of Skjærstadfjorden has been sought from the official navigation maps produced by Norges Sjøkartverk. Other information used for assessing the potential rate of depuration of stranded oil has been sought from scientific literature treating oil spill in cold water regimes.

5.2.4 Possible impact of a production accident

The appraisal will concentrate on the impact of oil drifting ashore, which in this context is considered the only real treat from the Heidrun development. It is not expected that the base activites or ship and helicopter traffic will have any impact with the exception that the possible establishment of a supply base (e.g. Hummelvik, cf. chapter 2), will cause local physical alteration and substrate disturbance during construction. Other known discharges in the Heidrun area: production water, sewage, and drill mud on cuttings are not likely to have any impact on the nearshore or shore region, due to extensive dilution before possibly reaching the coast or sedimentation around the platform.

The main effect of oil on the shore system will be by smothering. From a geochemical point of view, the effects on erosion substrates will be physical only.

On transport and to a greater extent on depostion substrates oil will also cause chemical alteration of the sediment. The chemical alterations are, besides increased hydrocarbon level, mainly a shift in the redox regime to more reducing condition. The redox profile of sediments in general are characterized by oxygenated condition (redox values of 150-200 mV) in the upper 0.5-20 cm depending on grain size distribution. Below this there is a discontinuity layer where the redox value drops sharply to suboxic or reducing conditions. When smothering from oil occurs, the discontinuity layer will rise towards the sediment surface, partly because oil reduces the gas exchange between the sediment and the water/air above, partly because biodegradation of the oil demands oxygen that may be taken from the oxygen pool in the surface sediment. A third factor acting the same way is that oil may reduce animal activity (bioturbation) in the sediment and through that reduce the vertical exchange of pore water and oxygen. The result may be that anoxic conditions are generated all the way to the sediment surface. Apart from making the sediments inhabitable for most biota, the sediment chemistry may be altered due to sensitive redox reactions.

When oil hits a shoreline the first impact phase will be followed by a depuration phase when oil is gradually lost from the shore system, either by cleanup procedures or natural processes such as erosion, dislodging, redistribution, biodegradation and photo-oxidation.

During the phase of oil removal or erosion longer term impacts may occur. Oil trapped in crevices or sediment may continuously leak small amounts of toxic compounds to the environment, either from components in the oil or as products of photo- and biodegradation processes of less harmful hydrocarbons. This phase resembles a chronic oil or petrochemical discharge.

5.2.5 Factors affecting the rate of loss of oil from the shore system

Most data on shoreline oil pollution originates from investigations following nearshore spills such as from tanker groundings or storage tank rupture. As outlined in Chapter 5.1 oil drifting ashore from the Heidrun field will be at least 5 days old, and will in general have lost its toxic components by evaporation and dissolution before the coast is reached. Experience from tanker groundings are therefore in many cases of reduced value in assessing potential initial damage from an oil spill from Heidrun. On the other hand the time needed for a stranded oil to be removed from an area of the shore is less dependent on how long the oil has drifted before landing, and tanker accident experience is in this respect in general valid.

Several factors will have to be considered when assessing the rate of oil removal:

A. Features of the oil.

The type of oil determines the degree of dispersion and emulsification, and degree of penetration into sedimentary bottoms. A light, low viscosity oil will penetrate deeper into sediments than a heavy or weathered oil. The amount of oil brought into the subtidal is also dependent on the specific weight of the oil and the dispersion and emulsification processes all of which are partially functions of oil type.

The volume of oil determines primarily the degree of smothering and the extent of coastline impacted.

B. Features of the physical environment

The wind condition determines the extent of spreading of the oil both horizontally and vertically on the coast. The effect of wind is mainly through its generation of waves. In rough weather the physical dispersion of the oil increases and oil droplets and emulsions may be brought down to the subtidal. Adherence of oil to suspended sediment particles may increase the specific weight of the oily material sufficiently to make it sink. Heavy wind will also cause oil to strike the supralittoral zone, and facilitates redistribution of the oil to areas not impacted by the initial stranding.

Wave exposure determines both the inital horizontal and vertical spreading of the oil, the degree of dispersion and redistribution, and the rate of self cleaning after a spill. On erosion shores waves may mechanically break down and redistribute stranded oil, and on transport shores they may cause both burial and erosion of the oil. The effects of waves on depositional shores is small. The rate of the processes is a direct function of wave energy. On high energy beaches with strong waves the oil will be removed in a relatively short time (a matter of weeks), whereas wave-sheltered shores may act as sinks for recently deposited or redistributed oil. In sheltered areas the supralittoral zone is less likely to receive oil.

Tidal range determines the vertical range of the area where the oil initially may smother the shoreline, and hence the sector of the community that will be initially impacted. Oil that is deposited on a shore during falling tide may be lifted off the substrate again at rising tide. During extreme high tide oil may be lifted up into the zone of supralittoral vegetation. The tide also determines the level of interstitial water in sandy to bouldery shores, and vertical tidal pulsing of this water table may cause oil to be transported into the sediment by percolation at falling tide. Although the real difference in water level between high and low tide is dependent on other factors than the basic tidal rythm, such as wind direction and air pressure, the average tidal range on the coast in question: around 2 meters, is large compared to other sites south of the impact zone (Table 5.2.1).

Table 5.2.1. Vertical tidal amplitude (meters) for selected sites along the Norwegian Coast. (Norges Sjøkartverk 1981)

site	Within the impact zone	Mean difference between	
		MHT and MLT	EHT and ELT
Vardø	-	2.01	2.59
Andenes	+	1.77	2.32
Narvik	+	1.87	2.55
Bodø	+	1.65	2.22
Mosjøen	+	1.73	2.34
Rørvik	+	1.55	2.08
Trondheim	+	1.83	2.47
Ålesund	-	1.22	1.64
Bergen	-	0.88	1.19
Mandal	-	0.17	0.22
Oslo	-	0.24	0.32

Temperature mainly determines the viscosity of the oil which again determines the degree of emulsification and dispersion and the ability of the oil to penetrate into sediments on the shores. Sea ice formation will dampen the abrasive effects of waves on the oiled shores, and if oil is entrapped in or under the ice the weathering processes may be slowed down or stopped.

The physical structure of the shore determines the residence time of the oil after a spill. On smooth rocky headlands the oil is easily washed off by the waves, and residence time is a direct function of wave exposure. The more uneven and cracked the rock surface is, the less of the wave energy goes to erosion of the oil, and the retention time will increase. Oil trapped in cracks and crevices or between boulders may leak out and cause secondary long-lasting pollution (e.g., Wikander 1982).

Where loose material is present on shores oil will penetrate into the interstitial spaces between rocks or sand grains, or it can be buried under sediment moved by the waves. The degree of penetration depends on the oil viscosity and volume, and the sediment porosity. On fine-grained sand beaches only low viscosity oils will penetrate significantly, whereas on bouldery shores even heavy, tarry oils can rapidly penetrate down to the ground water table (Owens 1978). Oil buried in sediment or between rocks will not easily be eroded by waves and may persist for many years (e.g., Gundlach & al. 1982) gradually leaking hydrocarbons to the surroundings.

Oil adsorbed to suspended particles and sand-encrusted water-in-oil emulsions (mousse) may be transported to subtidal bottoms and finally accumulate in depositional sediments (Beslier & al 1980), where the removal is slower than on beaches. Oil droplets may also be ingested by zooplankton and discharged as sinking faecal material (Conover 1971). Still the amount of oil reaching subtidal bottoms will never be as high as on the shore. Significant amounts of oily material settling on subtidal hard bottoms have not been reported, and since high wave energy is a prerequisite for transporting oil down into the water, any material settling on subtidal rock bottoms will rapidly be resuspended, and if encrusted with sand grains, eventually reach depositional bottoms.

The season will have influence on the fate of oil discharged to the sea, since both wind, temperature, and light are seasonal along the Norwegian coast. Both the extent of oil drift (cf. chapter 4) and rates of changes in the oil such as dispersion, emulsification, photooxidation and biodegradation are therefore dependent on season. The seasonal climatic change will also influence the long term fate of stranded oil. During cold periods the oil may harden and be less accessible to erosion and degradation. When temperature increases the oil may become less viscous again and leak out into areas which have become clean (Thomas 1973, Wikander 1982).

5.2.6 Oil removal rates - selfcleaning ability

It is clear from the aspects listed in the previous section that the rates at which oil will be removed after stranding will vary considerably from one shore/sediment type to another and that valid predictions and generalizations are hard to make.

Since oil removal primarily is caused by the abrasive effect of waves, any oil that strikes above the surf zone will be very persistent. The removing forces here will be photochemical and biological degradation both of which are dependent on a large surface to volume ratio of the oil to be effective. One must therefore expect that, unless the oil is removed mechanically, heavier oiling in the supralittoral zone will remain for several decades, either hardening to an asphalt "pavement" or gradually being buried under new plant material (Gundlach & al. 1982).

In the tidal zone the rates are more varied. One year after the "Dei Fovos" grounding off the Helgeland coast in 1981, the impact areas were revisited (Wikander 1982). The shores in question had a mixture of erosion and transport substrates. Oil had struck supralittorally and in the upper part of the tidal zone. Although weathering of the oil had proceeded, the oil cover was apparently not much reduced since the spill, and gave a blue sheen on the water. During a visit after 2.5 years (Danielsen & al. 1985) the appearance was much the same. After 3.5 years the oil in open areas had become more asphalt-like, but was still soft and sticky between rocks and boulders, and produced a blue sheen (ibid.).

To our knowledge the "Dei Fovos" site has not been reinvestigated after that, but local authorities (Nesna kommune, teknisk rådmann) have informed that no apparent contamination excists today in the area. One must therefore expect that most of the oil has either been eroded away, degraded, solidified, or has been buried during the 6 years since the stranding, sufficiently enough not to cause public concern any more.

Reinvestigation 6 years after the "Arrow" spill in Nova Scotia also revealed remnants of oil buried in the sediment. In some areas asphalt pavements were present, still leaking oil to its surroundings (Keizer & al. 1978).

The areas of impact from the tanker "Metula" spill in the Strait of Magellan (at 53^0 south latitude) were revisited after 6.5 years (Gundlach & al. 1982). On low wave energy sand and gravel beaches it was previously estimated that the oil would remain for 2 - 3 years. This was now extended to about 15 years. Oil removal from marshland areas had been estimated to 20 years and was now extended to more than 100 years. Within sheltered tidal flats there was no reason to believe that the buried oil would ever be physically removed, unless the whole tidal flat area was eroded away.

Gundlach and Reed (1986) have on basis of this and a series of other major spills as well as field experiments, computed simplified oil removal coefficients for a range of cold water tidal zone biotopes (Table 5.2.2). The removal rates range from 99% lost within 5 days on exposed rocky shores and water saturated tidal flats to 0.5-5% loss in the same period in marsh areas.

Removal rates in subtidal areas are also dependent on water movement, or more specifically on rate of sediment accetion and resuspension. The oil entering these sites will be in particulate form, either as oil adhering to sinking particles or as sand-incrusted oily material transported down from the tidal zone. On transport substrates with coarse material (gravel or sand), fine grained material including oily particles on the surface will tend to be resuspended, but under certain conditions (e.g. bioturbation, hypersedimentation) such material may also be buried. On silty and muddy substrates the oiled material will accumulate (Beslier & al. 1980), and loss is a function of slow dissolution and biological degradation, much the same as on sheltered soft sediment beaches (Berge & al 1987). The reworking of sediment by animals (bioturbation) can cause significant burial to a depth of 10-50 cm and alteration of the oiled material (e.g., Gordon & al. 1978). How this affects the residence time is however uncertain since bioturbation can cause both burial and increased mineralization of the oil.

Table 5.2-2. Generalized daily oil removal rates as function of shoreline type and wave energy (From Gundlach and Reed 1986).

Shore type	Percent removed	
	in 1 day	in 5 days
Rocky shores		
exposed	60-63	99-99.3
sheltered	5-10	5-22
Sand beaches		
Low wave activity		
beach face	18-26	63-78
backshore	10-18	40-53
High wave activity	40-45	92-95
Gravel beaches		
Low wave activity		
beach face	10-18	40-53
backshore	5-10	22-40
High wave activity	33-40	86-92
Tidal flats (wetted)	60-63	99-99.3
Marshes	0.1-1	0.5-5

To summarize, the self cleaning ability on a physical basis will be small on depositional substrates, with removal time in the range of 10-100 years or more depending on conditions and intial degree of smothering. On transport substrates the self cleaning will be small to medium, and removal times of 1-10 years are realistic to expect. If oil becomes deeply buried on sandy shores one must expect longer time. On erosion substrates the self cleaning ability will be medium to great mainly as function of roughness of the substrate. On smooth rocky headlands and subtidal hard bottoms residence time will be in the range of hours to months. On bouldery and gravelly shores removal time of 1-10 years must be expected.

5.2.7 Vulnerable shoreline locations in the impact region.

Figures 5.2.1 to 5.2.3 give the distribution of the classes of shoreline substrates in the impact region. One should note that the figures indicate only the main type of shore, and that smaller stretches of other types may be interspaced between these. A more detailed account of the shore types is given by the SINTEF map series (Hoddø & al. 1984, Klokk & al. 1984, Tømmerås & al. 1985).

Corresponding information on distribution of bottom types in the subtidal do not exist, but one must expect that shallow water depositional sediments co-occur with similar sediments on the shore.

County of Nordland (Figure 5.2.1 and 5.2.2)

The county has a shoreline of about 4200 km on the mainland and 9700 km on islands and skerries.

Depositional substrates are scarce in Nordland. They are characteristic as small patches in the vicinity of river outfalls at the inner end of some of the fjords, but do also occur in sheltered bays close to the open coast in Lofoten. The higher frequency of silty and muddy shores in Lofoten ties in with the general dominance of sedimentary shores in this region.

Transport substrates are scattered along the whole of the county, often in relatively exposed shallow bays at the outer coast. The most comprehensive stretches of sandy shores are found at Andøya and at Sømna south of Brønnøysund. Also the region Nesna-Lurøy and Meløy-Gildeskål have frequent small stretches of sandy shores.

Erosion shores are the dominating shore class in the county. We have distinguished between boulder-gravel shores and smooth/serrated

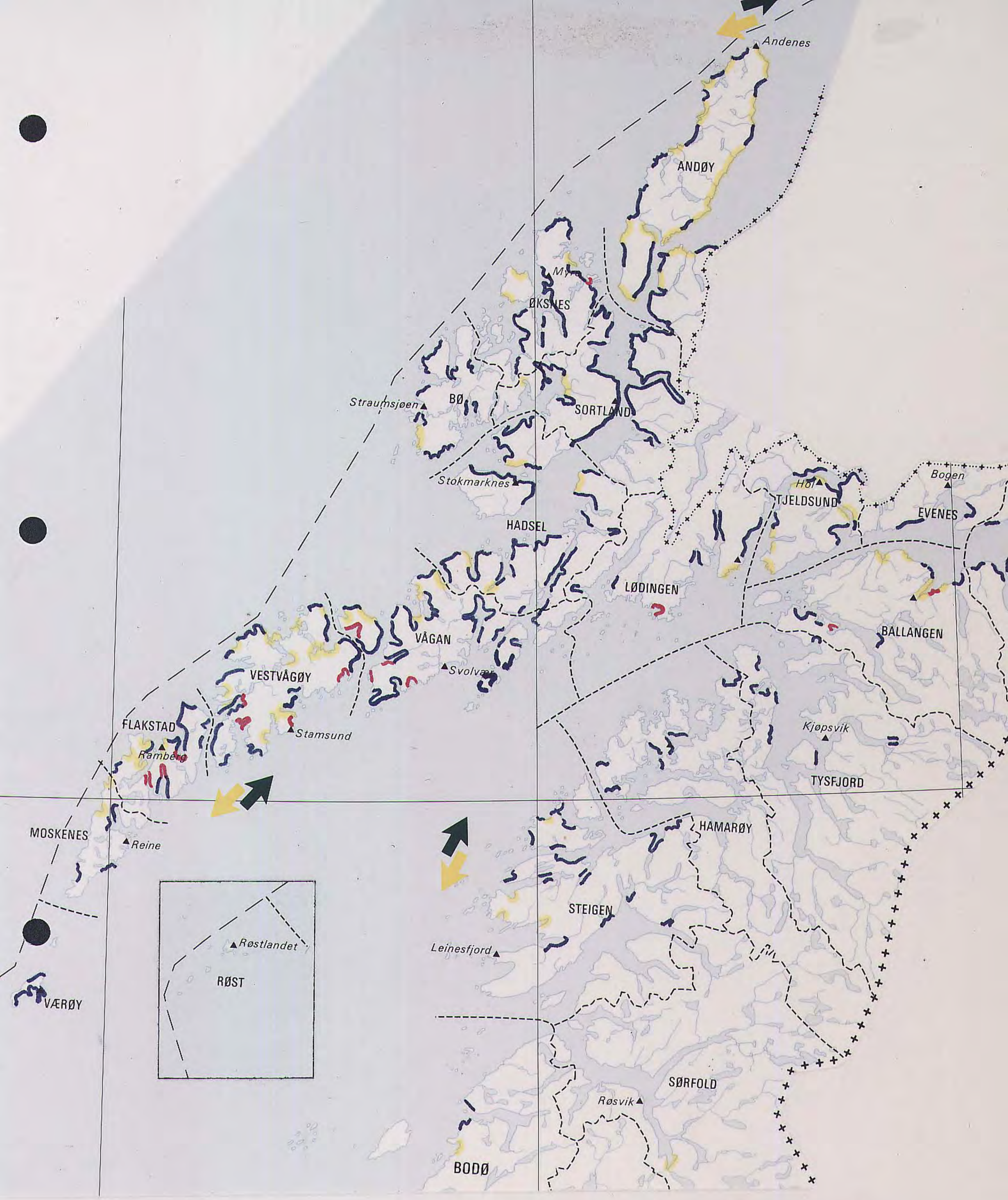


Figure 5.2.1. Map of the Nordland county north of Bodø indicating the main distribution of bottom substrate types in the tidal zone. ——: depositional bottoms, ——: transport bottoms, ——: erosion bottoms with loose material, no line: bedrock substrate. Impact zones: ➡ ⬅ high, ➡ ⬅ medium, ➡ ⬅ low.

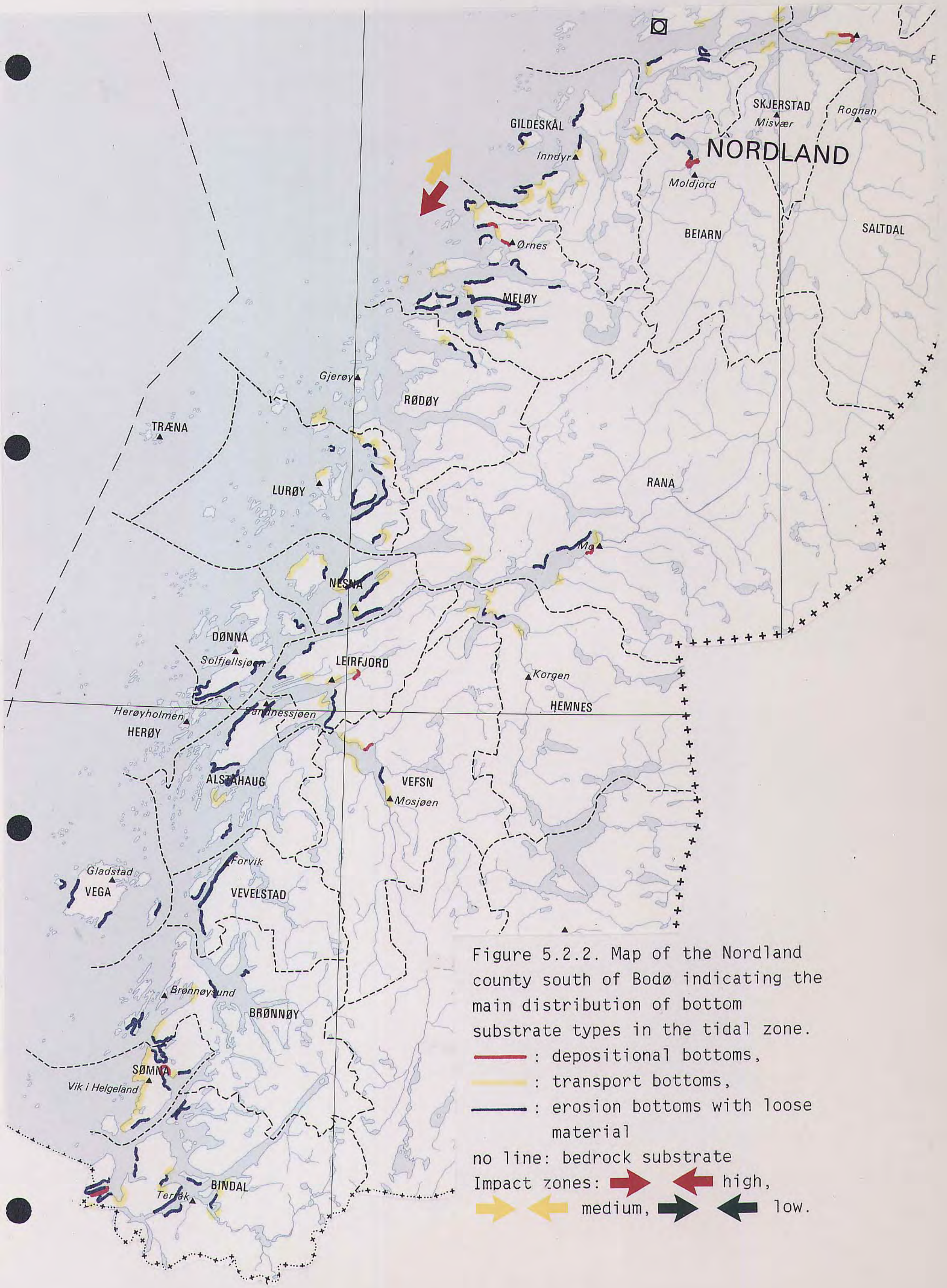


Figure 5.2.2. Map of the Nordland county south of Bodø indicating the main distribution of bottom substrate types in the tidal zone.
red line: depositional bottoms,
yellow line: transport bottoms,
dark blue line: erosion bottoms with loose material
no line: bedrock substrate
Impact zones: red arrows high, yellow arrows medium, dark arrows low.

bedrock shores in the figures as self cleaning ability in general will be higher on the latter. Boulders, stones and gravel dominate the shores of the Lofoten and Vesterålen region, and are frequent on the outer coast in the rest of the county. Bedrock shores dominate in the Narvik-Bodø region and along the sides of the fjords in Helgeland.

County of Nord-Trøndelag (Figure 5.2.3)

The county has a shoreline of about 1300 km on the mainland and 2500 km on islands and skerries.

On the outer coast depositional substrates are only found in a few smaller bays NW of Namsos. The main muddy shores are found in the inner part of Trondheimsfjorden, and here they constitute the dominating shore type both in Levanger, Inderøy, and Steinkjer municipalities. Depositional shores also dominate the inner end of Namsfjorden at Namsos.

Transport shores occur most frequently along the fjords NW of Namsos. They are also found scattered on the open coast as well as amongst the more muddy bottoms in inner Trondheimsfjord.

Erosion shores are the dominating coastal shore type. Shores with boulders and stones are found scattered mainly from Flatanger to Fosnes municipality, whereas solid bedrock dominates in Nærøy and Vikna.

County of Sør-Trøndelag (Figure 5.2.3)

The county has a shoreline of about 1200 km on the mainland and 3900 km on islands and skerries.

Depositional shores are scarce. The SINTEF maps indicate only 3 stretches of any significance: Strømmen in Rissa, Gulosen south of Trondheim and in Snillfjord, of which Gulosen is the largest.

Transport shores are found most frequently in Bjugn municipality and along the Trondheimsfjord. Erosion substrates dominate the shores of the county. Boulders, stones and gravel dominate the shores in Åfjord and Ørland, as well as along considerable stretches in the Trondheimsfjord. In the other coastal municipalities solid bedrock shores dominate.

Figure 5.2.3. Map of the Nord- and Sør-Trøndelag counties indicating the main distribution of bottom substrate types in the tidal zone. ——: depositional bottoms, ——: transport bottoms, ——: erosion bottoms with loose material, no line: bedrock substrate.
Impact zone: ➡ ⬅ high, ➡ ⬅ medium, ➡ ⬅ low.

5.2.8 Conclusions

The coast of potential impact is long and with an extremely complicated topography. Although the majorities of shores are of erosion type there are vast stretches of shores and shallow subtidal areas with boulders, stones and finer material where oil may accumulate. Furthermore, the relatively large tidal range in the region compared to shores further south, increases the potential vertical distribution of stranded oil, and will also facilitate penetration of oil into sandy sediments. On the other hand the majority of the most vulnerable depositional shores are found inside fjords. Although it is not the task of the present analysis to assess the feasibilty of oil combat in the various regions, it should be logistically feasible to prevent large amounts of oil from entering several of these fjords.

In the high impact zone from Vikna to Meløy we expect that large amounts of the oil will be collected in the outer part of the coast on shores with loose material (boulders to sand). Much of the oil will probably also be thrown up on land on the skerries if the weather is rough, especially between Vega and Lurøy where the sea is shallow and density of skerries is high. Still some of the oil may pass the outer coast, especially during a large spill. Oil which is transported into the fjords will be quickly eroded away from the smooth sides of the fjords and may finally accumulate on stony or sandy shores, in sheltered bays, and in the innermost part of the fjord where there usually are at least some depositional shore areas. On the other hand, larger shores with depositional sediment, where residence time would be especially long, are nearly non-existent in the high impact zone.

In the northern medium impact zone oil will have the longest residence time if coming ashore in the Lofoten-Andøya region. The Lofoten region is considered most vulnerable due to frequent occurrence of sandy and muddy shores fairly close to the open coast, but in general the whole of the Lofoten-Andøya region is considered vulnerable. It should be noted in this connection that this region is only included in the medium impact zone during June-August, when the the weather is relatively calm compared to other seasons, and that the spill modelling then predicts a mean drifting time of 25 days or more, before the oil hits the coast at Lofoten. The possiblity of taking precautions against oil stranding on the most valued shores should therefore be good.

In the rest of the northern medium impact zone the outer coast is expected to have strong self cleaning ability and stranded oil will probably be redistributed and accumulate in the fjords and landlocked bays.

In the southern medium impact zone the self cleaning ability of the outer coast is also considered large. Most of the shores are erosional, mainly bedrock. The coast along Frøya and the Froan archipelago have very complicated topography with dense occurence of skerries, smaller bays, and tide flats where oil may be thrown on land and be trapped for long time.

Still, the most long-lasting impact is expected if the oil enters the larger fjords of the southern region: the fjord system in Namsos municipality, and especially Trondheimsfjorden. The dominating occurrence of transport and depositional shores in the latter, makes it likely that oil entering the fjord will remain in the shore system for a very long time. Hence, all means should be used to prevent oil from entering this fjord.

5.3 FISH SPAWNING GROUNDS

5.3.1 General

A distinct difference between off-shore and inshore spawning grounds is somewhat artificial since several of the species and populations (cod) may spawn both inshore and offshore depending on environmental conditions (Ellertsen et al. 1981). Systematically collected information on the location of inshore spawning grounds along the coast is scarce. The evaluation of impact on inshore spawning grounds is thus based on general knowledge of the biology of the species. Species which mainly spawn in the fjords or in near-shore areas inside the "grunnlinjen" (a line drawn between specific points along coast) are considered. Several littoral species found along the coast are not mentioned explicitly mainly because their importance as an exploited resource is negligible, but also because the effect of oil on the majority of these species is not known and can only be guessed from the experience from other species. Since the distinction between off-shore and inshore areas is somewhat artificial species treated in the off-shore section are not mentioned in spite of their occurrence in inshore areas. Generally species mentioned to be potentially affected in the offshore region will have far less probability of being affected in the inshore region because of distance and wheathering of potentially spilled oil.

5.3.2 Oil on inshore spawning grounds

Less than 5 days old oil will in case of a blow-out on the Heidrun field under the worst possible conditions (minimum drift time) only have the possibility of reaching inshore areas in December to February (Chapter 4). Under mean conditions (mean drift time) less than five days old oil is not expected to reach inshore areas at all (Chapter 4) and less than 10 days old oil will reach the coast only in December to February in the area from Vikna to Leka (Chapter 4). This implies that the introduction of fresh oil (<5 days old) to inshore areas is virtually excluded and ecologically significant concentrations of soluble petroleum hydrocarbons are thus not expected to be found in the water masses in inshore areas because of an oil spill on the Heidrun field. Consequently pelagic fish, eggs and larva in the inshore areas are not expected to be directly influenced by toxic components originating from oil spilled in the Heidrun field. Fish which spawn or have nursery grounds intertidally may however be affected, mainly by stranded oil smothering their habitat. Stranded oil may also, to a limited degree be redistributed to nearshore subtidal areas by adherring to eroded particles which are subsequently transported to the subtidal through sedimentation.

5.3.3 Fish species in inshore areas

Coastal populations of cod (Gadus morhua).

Local populations of cod are found along the Norwegian coast from inshore areas and out to the coastal banks. These populations do not perform major migrations like the Arcto-Norwegian population and spawn along the whole Norwegian coast and in fjords (see Ch. 3, Fig. 3.3.3).

There is no reason to belive that the physiological tolerance to oil is any different in coastal populations of cod than for the Arcto-Norwegian cod. The potential direct effects on spawning of coastal cod are expected to be insignificant because biological significant concentrations (>50 ppb) are not expected in the water masses inshore as result of any activity in the Heidrun field. The nursery ground of the coastal populations of cod is vertically distributed from the Laminaria zone and deeper, mainly in areas with rocky substrate, sand and mudflats. Subtidal rocky substrates are not likely to receive significant amounts of oil after an oilspill. Thus, nursery grounds for cod are not vulnerable to the activities related to development and production in the Heidrun field.

Flatfish

Several species of flatfish are found in inshore areas and are commercially exploited (halibut, plaice, flounder).

Halibut (Hippoglossus hipoglossus).

The halibut is as adult confined to deep waters (300- 2000 m) and spawn at 300-700 m depth in fjords and deep depressions in the sea floor on coastal banks in the period December to April. The eggs float up to the pycnocline (Salinity 34-34.5 o/oo, temp. 4.5-7^{0}C, depth 100-250m, see Haug et al. 1984) where the eggs hatch after two weeks. Folda, Salten, Trondheimsfjorden and coastal areas of Møre and Romsdal are known spawning grounds (Kjørsvik et al. 1987 and Haug et al. 1984). When larvae reach 3-3.5 cm they seek to the bottom. The exact habitat for juvenile halibut is not known.

Because of its depth distribution the halibut is not expected to be influenced by offhore activity in the Heidrun field. However, a reservation must be included for the juveniles if their nursery grounds are to be found in intertidal or shallow subtidal mudflats.

Plaice (Plauronectes platessa) and Flounder (Platichthys flesus)

The plaice is usually found between 10 and 50 m depth. This species spawns in February to March in Northern Norway. Spawning grounds are not clearly defined. Spawning takes place on the bottom (20-40 m). After spawning the eggs float to the surface water where they are planktonic for approximately 20 days until they hatch. Adult fish perform feeding migrations to intertidal mud- and sand-flats during the summer. Intertidal areas are important nursery grounds for the plaice. It is therefore clear that eggs and juveniles of plaice may be smothered by oil coming ashore.

The distribution of flounder overlaps with the distribution of the plaice, but flounder is encountered in more brackish water. The reproduction behaviour of the plaice and flounder is very similar and hybridisation (fertilization across species giving viable offspring) has been documented.

Effects of oil on adult flatfish have been documented after the "Amoco Cadiz" spill. In estuaries affected by the oil, macroscopic effects like fin and tail necrosis were seen in flatfish and also several histopathological and reproductive disturbances (Haensly et al. 1982, Brule, 1987). Such effects are likely to be less in case of an oil spill on the Heidrun field since the oil rereaching inshore areas will be more weathered than was the case after the "Amoco Cadiz" spill.

Salmon (Salmo salar) and sea trout (Salmo trutta).

Both these species are anadromous (fish which spend most of their lives in the sea (feeding migration) and migrate to freshwater to breed). The salmon perform feeding migration to off-shore areas and the trout to more inshore areas. The spawning of the two species takes place in freshwater in October-November in rivers along the whole Norwegian coast, and will consequently not be directly affected by any event on the Heidrun field. The migration in the sea takes place in the surface water. During the migration fish might theoretically come in contact with oil in case of a major oilspill which is transported to inshore areas. The river outlets are in general located in the inner end of the fjords where also the density of migrating salmon and trout is highest. The probability of oil originating from an offshore oilspill reaching the inner end of a fjord is unlikely and even if this happened adult fish are not likely to be affected because the toxic soluble components will have been lost from the oil. We assume that the potential effects of offshore activity on spawning of salmon and trout are negligible. There have, however, been some speculations on the effect of hydrocarbons on olfactory mechanisms of orientation (Stabell, 1983).

Shallow water fish species without direct commercial value.

Several species spawn and/or have their nursery grounds in shallow waters along the coast. Generally these species migrate to deeper waters during the winter. Some of these species like the sand goby (Pomatoschistus minutus) are not of direct commercial value, but are predated by commercially important species like cod. Shallow water species are vulnerable since it is difficult to avoid spilled oil reaching the coast where it may acumulate and be present for years, especially in sand and mudflats. Species with benthic eggs like the sand goby are most vulnerable to smothering.

The effect of an oilspill on local populations of shallow water fishes especially in the intertidal area during the summer may be significant mainly by smothering of the habitat. A spill in the winter will not have an immediate effect since the fish are located in deeper waters. A possible long term effect will be a function of the depuration of hydrocarbons initially incorporated in the sediment, the amount of soluble components in such oil and the degree of smothering of the habitat.

The edible crab (Cancer pagurus).

This species lives during the summer from the lower shore and down to 30 m. During the winter it is confined to somewhat deeper waters (30-50 m). The edible crab prefers a firm substrate of rock, boulders or hard clay or sand. It spawns in the autumn and the fertilized eggs are retained by the female until next summer when they are released to surface waters. No defined spawning grounds are known and it is assumed that it takes place along the whole of the coast up to Lofoten. It is not expected that the edible crab will be significantly affected by the activity on the Heidrun field because its habitat (below the lower shore) is not likely to be seriously smothered by stranded oil.

5.3.4 Pathological effects of hydrocarbons on fish.

Adult fish can be killed by oil spills (Hampson and Sanders, 1969), but this probably poses less of a threat to commercial fisheries than does damage to eggs and larvae (Teal and Howarth, 1984). Pathological effects on adult fish are mainly confined to coastal and inshore areas where petroleum hydrocarbons may persist in sediments for years after a spill.

A detailed review of pathological effects of hydrocarbons is not within the scope of this report. It is, however, important to note that fish are equipped with detoxifying system (MFO-system) for hydrocarbons (see Spies et al. 1982 with references). Within limits fish can eliminate xenobiotics encountered in the environment. Effects of oil on adult fish are, however, documented for flatfish after the "Amoco Cadiz" spill. In estuaries heavily affected by the oil, macroscopic effects like fin and tail necroses were seen in flatfish and also several histopathological and reproductive disturbances (Haensly et al. 1982, Brule, 1987).

The "Amoco Cadiz" grounded on the coast resulting in relativly unweathered oil reaching shallow water areas and being incorporated in the sediment where it may persist for years giving chronic effects on adult fish and juveniles inhabiting sedimentary habitats. An oil-spill in the Heidrun field is likly to take 5-10 days before it reaches the coast. Thus effects on flatfish would probably be more limited both because the oil would be more weathered and because intertidally sedimentary habitats are scarce compared to shores on the continent.

5.3.5 Conclusion

The probability of oil reaching inshore areas is large. The content of soluble components in stranded oil spilled on the Heidrun field, however, is relatively low and will most likely not result in ecologically significant concentrations of soluble petroleum components in inshore water masses except in the immediate vicinity of large amounts of stranded oil. Consequently pelagic spawning grounds in the inshore area are not likely to be affected by offshore activities on the Heidrun field.

Stranded oil, however, may smother intertidal nursery grounds and spawning areas in the intertidal and is likely to be the most pronounced effect related to inshore spawning. These areas are most vulnerable during the summer season since their inhabitants usually migrate to deeper water during the winter season.

Pathological effects of oil on littoral fish have been documented after the "Amoco Cadiz" spill. Such effects can not be excluded in case of an oilspill on the Heidrun field. However, effects are likely to be more moderate because of the distance from the dischage to the shore.

5.4 INSHORE FISHERIES.

5.4.1 Introduction

The fisheries in Norway have traditionally been associated with coastal areas mainly on the coastal banks which in this report are included in the offshore section. Inshore fisheries (inside the outer skerries) have been of relatively limited commercial importance, except for prawns (Pandalus borealis), and localized fishing for cod (e.g, Borgundfjorden), at least since the 1950s. Fisheries for prawns are however prohibited in areas shallower than 100 m and is thus not expected to be influenced by the activity on the Heidrun field.

The importance of inshore areas have increased dramatically the last 10 years because of the the expansion of the aquaculture industry in Norway. This industry is at present mainly based on the cultivation of salmon (90 %) and trout (10 %). Other species of fish (cod, char, turbot, eel) and also mussels are cultivated to a limited degree or are at present cultivated on an experimental scale (halibut). These species are expected to increase in importance for aquaculture in inshore areas in the future. Based on production in 1986 (Anon., 1987a) and fishery statistics (Anon,1986) the total production of salmon and trout in Norway is approximately 1.6 % of the total catches from traditional fisheries. The direct commercial value of this is, however, 41 % of the traditional fisheries.

The production of salmon and trout in the four counties (Møre and Romsdal, Sør-Trøndelag, Nord-Trøndelag and Nordland) potentially affected by the activities related to the Heidrun field development comprises 50 % of the total production of these species in Norway in 1986 (Anon., 1987a).

The aquaculture industry has expanded dramatically. From 1985 to 1986 the production of salmon increased with a mean value of 50 % for the four counties potentially expected to be significantly influenced by the Heidrun field activities. The total production in aquaculture is expected to be 100 000 tons in 1990. The relative importance of aquaculture compared to traditional inshore fisheries is thus expected to increase even more in the future and will be the main focus of this section.

5.4.2. Aquaculture

Production forms for cultivating important fish or fish expected to become important in inshore areas are:

Intensive production in the sea: Reared fish are enclosed in cages in the sea. Growth of the fish is dependent on feeding. The food is usually based on raw-material from other species of fish of a more inferior quality and lower price. This production form dominates the present aquaculture industry. Salmon and trout production depend on freshwater hatcheries.

Extensive production in the sea: Larger sections of an estuary, fjord or bay are closed or partly closed from the rest of the sea with some sort of barrier. Fish stocks in the enclosure are partly dependent on natural prey organisms within the system and partly on food added to the system artificially. Fish stocks in the enclosure may be increased by the addition of fish from other sources. This production form is at present commercially insignificant, but may be more important in the future.

Land-based systems for aquaculture: Basins or similar structures on land which are supplied with water either from a freshwater or seawater source. Also included here are drained freshwater ponds filled with seawater for production of marine species. Land-based aquaculture is usually dependent on food from sources external to the system. Land-based systems are at present used for production of turbot, eels and for cultivation of juvenile cod.

5.4.3. Localization of aquaculture systems and production.

The localization of sea based aquaculture units is a compromise between reducing the effect of physical stress on the floating structures by locating the systems in sheltered areas and increasing the oxygen available by avoiding areas with low water currents. The construction and technology applied in building new floating aquaculture systems have recently been improved and the future trend will probably be to extend their distribution to more exposed areas with deeper water (Karlsson, 1986).

The distribution of the areas having high density of aquaculture sites along the coastline potentially influenced by the Heidrun field development is shown in Figures 5.4.1 to 5.4.3. Important areas are The islands Smøla, Hitra and Frøya in Sør-Trøndelag, the coastline

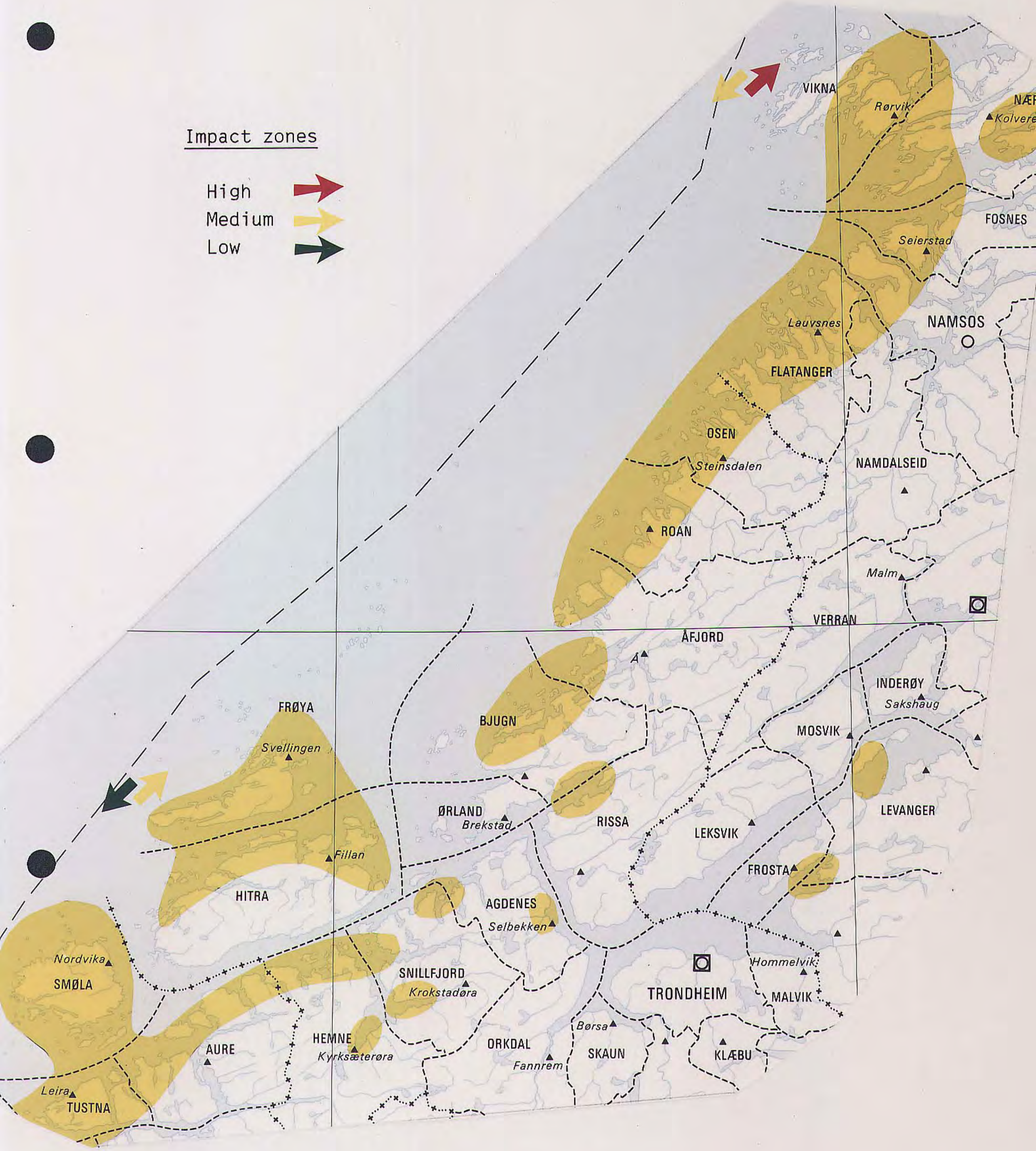


Fig. 5.4.1. Areas in the northern part of Möre og Romsdal, S-Tröndelag and N-Tröndelag to Vikna showing areas with high density of aquaculture plants. Sources: Klokk et al., 1984 (S-Tröndelag), Hoddö et al. 1984 (N-Tröndelag) and maps from fiskerisjefen i Tröndelag

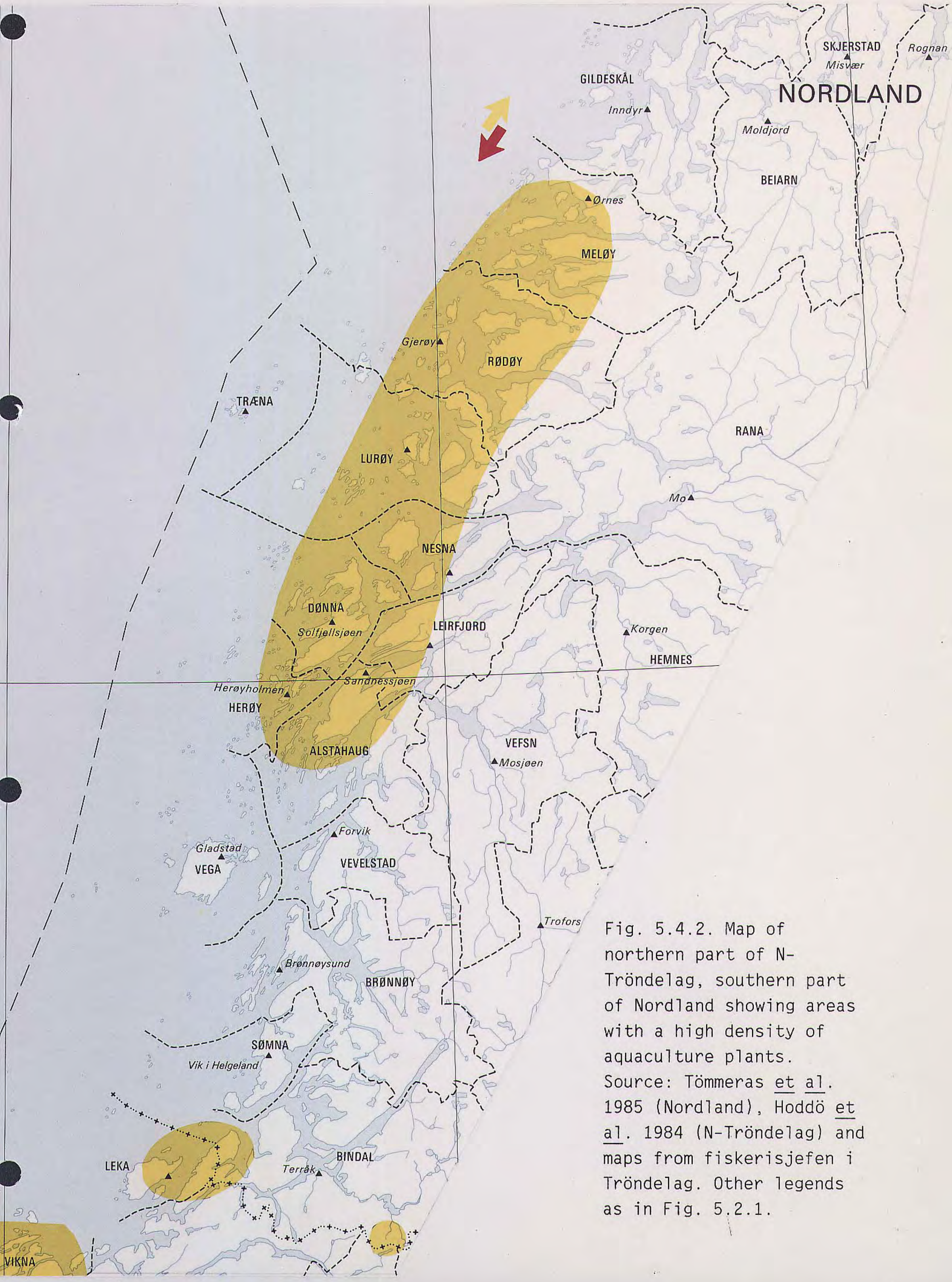


Fig. 5.4.2. Map of northern part of N-Tröndelag, southern part of Nordland showing areas with a high density of aquaculture plants. Source: Tömmeras et al. 1985 (Nordland), Hoddö et al. 1984 (N-Tröndelag) and maps from fiskerisjefen i Tröndelag. Other legends as in Fig. 5.2.1.

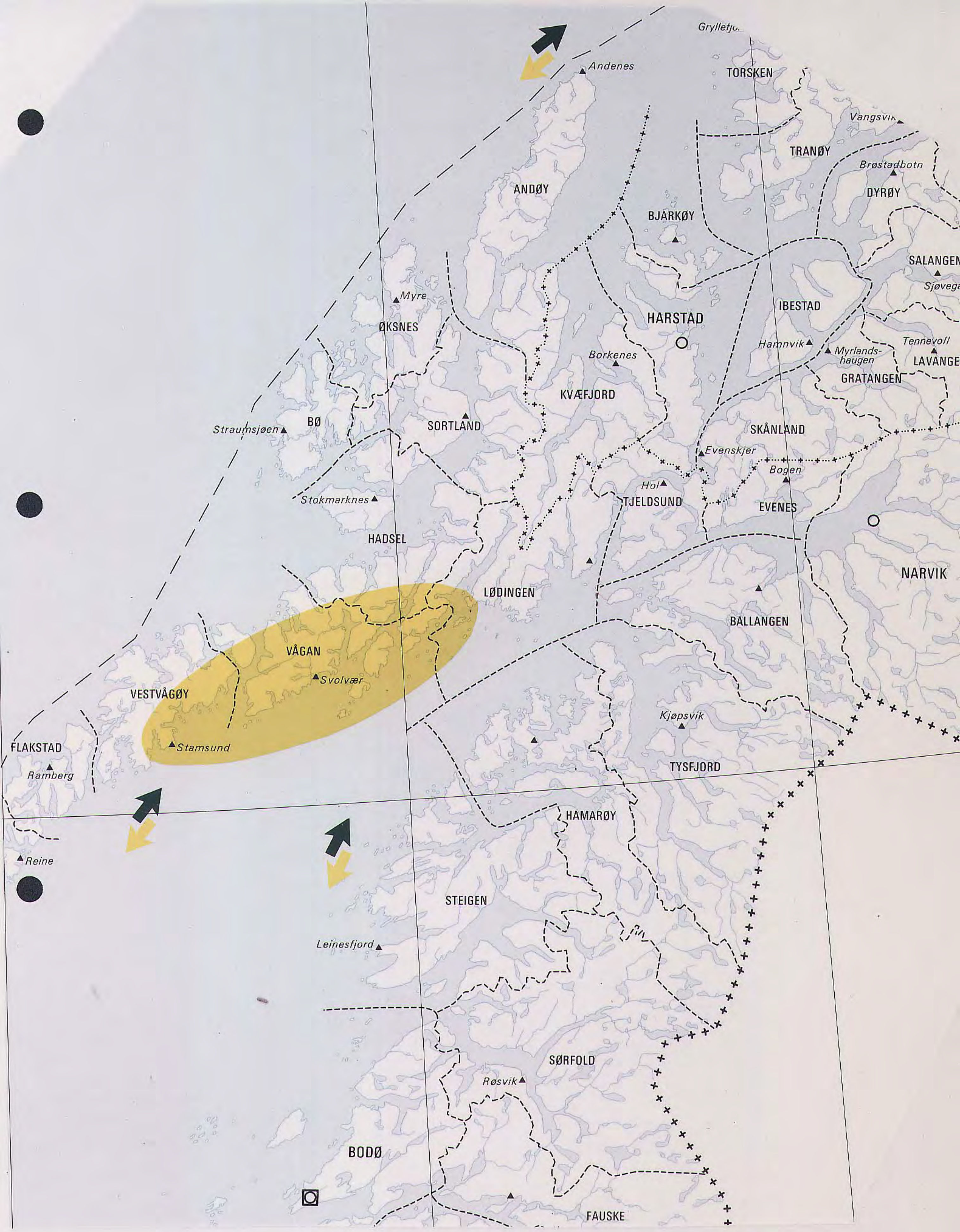


Fig. 5.4.3. Map of northern part of Nordland and part of Troms showing areas with a high density of aquaculture plants (Plants in Troms are not shown). Source: Tömmeras et al. 1985 (Nordland). Other legends as in Fig. 5.2.1.

from Bjugn to Vikan in Nord-Trøndelag and the coastline from Tjøtta to Meløy and the inner part of the Lofoten islands in Nordland. It is, however, important to stress that aquaculture is important also outside these areas and that no part of the coast can be totally excluded as a future location for aquaculture. A general trend at present is that the aquaculture systems are located on the outer part of the coast although avoiding the most exposed localities. The inner parts of the fjords are only sparsely used for aquaculture.

The number of aquaculture concessions in the counties potentially affected by the Heidrun field are seen in Table 5.4.1 and the totals for production in Table 5.4.2. It is important to note that the number of concessions for mussel production gives a biased impression of the aquaculture activity since only a fraction of these concessions have a functional unit. Of the 800 concessions for mussels in Norway only 40 have delivered mussels (Anon, 1987b)

5.4.4. Production forms relevant for aquaculture in Norway.

Salmon and trout

The salmonids which dominate the production in the aquaculture industry are anadromous fish which are hatched and reared in freshwater during the juvenile stages. Transfer to pens in sea water is performed in connection with smoltification (fish weight approximately 50 g). These pens or cages are typically constructed as a framework surrounded by a net protecting the fish from escaping. Salmonids are kept and fed in these pens for 1 - 3 years before they are slaughtered.

A critical parameter for salmonids is the availability and the concentration of oxygen in the water which should not be below 5 mg/l. The availability of oxygen is a function of the water renewal inside the fish cages, respiration by the fish and the remineralization in the sediment. The water renewal is determined by the local hydrographic conditions and the construction and positioning of the cages relative to topography and hydrography. Respiration is a function of the size and amount of fish in the cages, the ambient temperature and the amount of wastes from the food fed to the fish (Molvær, 1986).

Table 5.4.1. The number of aquaculture units (concessions) in Møre and Romsdal (pr 31.03.87*), Trøndelag (pr. May 1987**) and Nordland (pr. 1987***).

Area	Salmon/ trout	Salmon/ Trout, Juv.	Other fish	Mussels
Møre and Romsdal	95	75	9	212
Sør-Trøndelag	33	73	5	55
Nord-Trøndelag	22	53	5	35
Nordland	123	71	?	120

* Source: Fiskerisjefen i Møre og Romsdal
** Source: Fiskerisjefen i Trøndelag
*** Source: Oppdrettskonsulent Anne Breiby, Nordland Fylke

Table 5.4.2. Production (in 1000 kg) in aquaculture in the counties potentially affected by the Heidrun field development.

County	Salmon*	Trout*	Other fish	Mussels
Møre and Romsdal	6572	928		
Sør-Trøndelag	5039	342		
Nord-Trøndelag	2940	86		
Nordland	8617	343		

* Source: Anon., 1987.

Mussels

The species of mussels cultivated along the Norwegian coast are the blue mussel (Mytilus edulis), oyster (Ostrea edulis, Crossaster gigas) Iceland scallop (Chlamys islandica), and bay scallop (Pecten maximus). Of these 5 species the blue mussel is the most important species at present. The oysters are cultivated commercially only to a limited extent. Although the cultivation of scallops in Norway has developed to a stage where important problems have been solved (see Vahl, 1986), more research and development is needed before these species will be important in the aquaculture industry in Norway.

All bivalves relevant for aquaculture in Norway are filter feeders.

Growth in filter feeders relies on filtering planktonic organisms or other particles from their surrounding water. Primary production is confined to surface waters where the density of suspended particles available for filter feeders is large. As a consequence of this, cultivation of mussels is confined to surface waters.

Blue mussels

The production of this species is based on cultivation of larvae recruited from natural populations. The pelagic larvae are collected by natural settlement on vertical or horizontal ropes or plastic bands suspended near the surface. These larval collectors are later usually suspended vertically under some sort of raft for growth. A more time-consuming technique has been to remove the juvenile blue mussels from the collectors and place them into long tube-like nets which subsequently are suspended vertically in the sea. As the mussels grow they will penetrate the tube-like net and eventually all the mussels are on the outside with the byssus thread attaching them to the central tube-like net which at this stage only functions to suspend the mussels to the raft. Growth is reduced at salinities below 1.5 o/oo.

Oysters

Only the European oyster (<u>O. edulis</u>) is found naturally in Norway. Populations are sparse because larval production is disfavoured by low temperature. Below 12^{0}C no egg development takes place and at 15-16^{0}C spawning takes place only every 3-4 years. Cultivation of oysters in Norway is thus dependent on cultivated larvae. Larvae of <u>O. gigas</u> are not cultivated in Norway. Larvae of the European oyster have, however, been cultivated in Norway for many years (Gaarder and Bjerkan, 1934).

The traditional method for cultivation of larval oysters is based on using oyster ponds where a surface layer (0.5-1m) of freshwater over-lays a saline (>2.5 o/oo S) bottom water. These traditional oyster ponds communicate with the sea through a narrow passage where only the surface freshwater can pass. The temperature of the bottom water is increased because of the greenhouse effect. Adult oysters are added to these oyster ponds in April and will under favourable summer conditions spawn 3 months later and the offspring can be retrieved as they settle on special collectors. The production stability of this traditional system is with the present requirements not satisfactory and alternative systems using plastic bags are under development in Norway (Naas, 1987). The cultivation after the juvenile stage is usually performed in baskets suspended under a raft or on horisontal ropes.

Scallops

Both species of scallops relevant for aquaculture in Norway are subtidal species which for aquacultural purposes will be cultivated in near-surface water. Methods for cultivation of larvae are not at present developed for the Icelandic scallop and the experimental cultivation which has been performed has been based on natural recruitments. Methods for producing larvae of the bay scallop by cultivation are known (Gruffydd, 1972). Experiments designed to produce scallop larvae have been performed also in Norway (Vahl, 1986). The production of bay scallops in Norway must still be characterized as being on an experimental scale and of negligible importance for the aquaculture industry at present. The cultivation of both species of scallops after the juvenile stages is performed using different modifications of the methods used for oysters, placing the scallops in baskets or trays suspended vertically in surface water.

5.4.5. Effects of the Heidrun field activities on inshore fisheries

Hatcheries - rearing of juveniles

Hatching and initial development of larvae and juveniles of salmon and trout takes place in freshwater. Seawater is used after smoltification which generally is performed in the same sort of land-based production system. Seawater is also mixed with freshwater during the transfer of smolt from freshwater to seawater in order to adapt the fish to the increased salinity. The possibility for oil or other contaminants from the Heidrun field reaching the seawater supply pipelines for such land based systems is small. The oil which potentially could reach such areas would at least be 5-10 days old (cf. Chapter 2) leaching negligible amounts of soluble components to the water column. Furthermore, the seawater used for landbased systems is in most cases pumped from deep water (30-100m), and even in rough weather it is not likely that large amounts of oil droplets would be transported to this depth.

If an oilspill were to advance the water inlet to a salmon or trout hatchery there may be limited possibility to find a temporary alternative clean water supply. If soluble petroleum hydrocarbons were introduced to land-based systems for rearing of juveniles, however unlikely, the treshold for direct mortality is high compared to the concentrations expected. Moles & al. (1987) found in experiments with exposure of pink salmon alevins (Oncorhynchus gorbuscha) to water-soluble fractions of crude oil, that direct mortality did not occur at a concentration of 0.7 and 1.5 mg/l but did occur at 2.4 mg/l. They also found that alevins exposed to 0.7-2.4 mg/l in a simulated tidal cycle (freshwater and saltwater) were more sensitive to oil, had reduced yolk reserves, and accumulated more hydrocarbons than did alevins exposed to the same concentrations in freshwater. These concentrations are at least 1 order of magnitude higher than what can be expected even under a fresh oilslick and are not likely to occur in inshore areas as a consequence of other incidents than a spill in the immediate vicinity of a hatchery.

We thus conclude that land-based systems including hatcheries will not be affected by any of the activities related to the Heidrun field development.

Intensive production of fish in cages.

Production units for intensive cultivation of fish are found along the whole coastline potentially influenced by the Heidrun field development. In case of an oil incident (blow-out or rupture of submarine pipeline) and based on the density of aquaculture sites along the coast and their location on the outer part of the inshore area (see Fig. 5.4.1 - 5.4.3) it is probably not possible to avoid that floating weathered oil will reach some areas used for aquaculture.

The effect of oil on aquaculture has recently been demonstrated through the effect of the Claymore pipeline oil spill incident in November 1986 on the British sector of the North Sea (Anon., 1987). In this oil spill approximately 3000 tons of oil was spilt subsurfacely through a leakage of a pipeline and some of the oil hit the Norwegian coast after 10 days. No effects have been reported as a consequence of this spill except on aquaculture. In an aquaculture unit on Bulandet (Sogn og Fjordane) 100-1000 fish were reported to have died. The fish died as a consequence of damage to gills and integument.

It has been suggested that the damages seen on the fish may have been initiated by oil introduced into or on the cages. This has elicited an avoidance or fright response through olfaction of some soluble component of the oil. Because the fish were confined within a cage the increased swimming activity did not result in a reduction of the stimulus elicited by the oil and has probably resulted in panic and increased swimming activity causing physical damage to the fish.

Increased swimming activity has been reported to be triggered by petroleum hydrocarbons. Reiersen and Berge (1985) found increased activity at concentrations of water soluble fraction of crude oil between 25 and 100 ppb but reduced activity at concentrations above 200 ppb for a littoral fish. Increased mortality for littoral fish has also been found at concentrations below 1 ppm (Berge & al., 1983). For fish exposed to water soluble fractions of crude oil 96-h LC_{50} values are reported to be between 1.2 and 65 ppm (Connell and Miller, 1981). These values are far larger than can be expected for water soluble fractions under an oilslick which is 10 days old and which has drifted across most of the North Sea. Increased swimming activity and the resulting physical damages to fish are thus probably the most likely immediate effect if weathered oil hits fish farms.

Of the areas with a large number of aquaculture systems (Fig. 5.4.1 to 5.4.3) the areas from Alstadhaug to Meløy and part of the area south of Vikna are in the high impact area of oil from the Heidrun field. The Lofoten area is in the medium to low impact area as is also the important area for aquaculture around the islands Frøya and Hitra. The northern section of the coastline of Møre and Romsdal is in the low impact zone.

It is, however, important to stress that the distribution of the different impact zones is based on the mean amount and the age of the oil likely to reach the coast. This does not imply that a fish farm hit by oil in a low impact area will be any less affected than a farm in a high impact zone. We base this statement on the assumption that the behavioural response elicited by the oil, which is probably the most severe effect of oil on fish farms, is an off/on response triggered by some unknown, but low, critical concentration. Tainting is also a potential problem associated with intensive fish production and oil. Experimentally it has been shown, however, (Grahl-Nielsen, unpubl.) that tainting of salmon is reversible and after keeping the fish in clean water for one week the distaste can no longer be detected.

Extensive fouling and smothering of cages by oil may also potentially reduce the exchange of oxygen between the cage and the surroundings. An increase in swimming activity will also cause larger oxygen consumption by the fish and thereby increase the oxygen stress even further. Availability of oxygen is a critical factor for fish, especially for salmonids. Smothering of cages by oil is thus a direct threat to fish in cages used for aquaculture and may result in detrimental effects.

Cageing of fish caught by traditional inshore fisheries.

Herring, sprat and saithe caught in traditional inshore fisheries are occasionally kept alive in net cages in sheltered bays before delivery. Such schools of fish may react with a behaviour similar to the salmonids affected after the "Claymore" oil spill incident. The integument of both herring and sprat are extremely sensitive to physical contact because of the chance of loosing scales and the risk of infections. Schooling behaviour may also result in fish breaking out of the net cage if oil elicits an avoidance reaction simultaneously for all the fish in a school.

The coast from Flatanger to Brønnøysund and the inner part of the Trondheimsfjord contains areas with especially high densities of locations used for storing herring. The area from Flatanger to Brønnøysund is thus especially vulnerable since it also contains high density of aquaculture systems. Farming and caging in the inner Trondheimsfjord are less likely to be affected by a potential oil incident on the Heidrun field because oil is not likely to penetrate so deep into the fjord.

Mussels

All the species of bivalves used for aquaculture in Norway are filter feeders and select particles from the water mainly based on size and not on quality. This means that oil dispersed as droplets, adsorbed on particles, and soluble components will introduce petroleum hydrocarbons to the mussels. Filtering is however an active process which under unfavourable conditions may be stopped for a limited period of time. During such a period (days) the mussels are able to survive based on anarobic metabolism and can thus avoid effects of short term strong exposure in case of an oil spill.

Relatively high concentrations (5-1000 mg/l) are needed to trigger acute mortality from hydrocarbons in Mytilus (Craddock, 1977). Long-term exposure of Mytilus edulis to low concentrations of petroleum hydrocarbons results in several physiological changes related to the energy balance of the mussels (Axiak and George, 1987) and with increased mortality as the result. Widdows & al. (1982) conclude that petroleum hydrocarbons (30 ppb) have significant adverse effects on physiological and cellular conditions of Mytilus. However, if hydrocarbons are incorporated into mussel biomass by an oilspill, release of the hydrocarbons from the mussels is possible. Farrington

& al. (1982) have reported biological half-lives for selected petroleum compounds (n-alkanes, pristane, napthalenes and methyl phenanthrenes) in the range of 0.2-1.7 days after a brief (2 days) exposure to an oil spill. Widdows & al. (1985) report complete recovery of both physiological performance and tissue hydrocarbon level in mussels after approximately 55 days in clean water after a long-term exposure to diesel oil.

This indicates that contaminated mussels may recover completely after exposure to hydrocarbons. However, since the energy balance of the mussels is affected negatively, growth will be reduced resulting in reduced production for the mussel farm.

Another serious problem is tainting which is probably the most tangible potential effect on mussel farms after a major oil incident, not only because of the distaste, but rather because of the problem of marketing products from an area known to the public to have been affected by an oil spill (Tidmarsh and Ackman, 1986). After the "Amoco Cadiz" oil spill incident oyster cultures were badly damaged (Chasse, 1978) both because of some mortality and even more because of economical loss due to effects of tainting.

In the area potentially influenced by the Heidrun field development the blue mussel is the only mussel species which has any commercial importance. The highest density of blue mussel farms is found in the area from Flatanger to Leka, the northern part of which is within the high impact area during spring and summmer. (Table 5.1.1). This is the time of the year when the mussels spawn and obtain the bulk of their nutrient reserve. If oil from a spill on the Heidrun field was introduced to a mussel farm in the high impact area, a limited direct mortality would occur unless the mussels were directly smothered by the oil. If the oil is removed immediately (within 1 week) no significant effect would probably be seen on growth. Tainting is however probable. Evidence from Widdows & al. (1985) indicates that tainting will be eliminated within 2 months after contamination has been stopped.

Extensive production.

Extensive production in aquaculture is not at present commercially important. If oil were introduced to such areas an avoidance reaction would not result in similar reactions as was found after the Claymore pipeline rupture since the density of fish in such a system is much lower than in intensive production and allows fish to avoid the oil without physical damage caused by contact with other fish and cages.

Oil entering bays used for extensive production of fish will probably have insignificant effect on the reared fish, as on wild fish, apart from possibly in shallow water areas and for fish with high density of juveniles near the surface in shallow areas (intertidal zone). An oil spill will, however, cause considerable problems through smothering of cages, nets and other structures near the surface. These structures have to be cleaned by a process which will not reintroduce the oil and detergents into the environment.

Pathological effects on fish are judged to be limited for for adult pelagic fish inshore because the probability of concentrations of petroleum hydrocarbons above the threshold for effects in inshore free water masses is negligible. Pathological effects have however been documented after oil spills on the French coast ("Amoco Cadiz", "Gino") mainly for flatfish (Maurin, 1984). Ulcerations of the skin have been documented by Chasse (1978) and is suspected to be caused by hydrocarbons resident in the sediment which are gradually redistributed and made available to fish in or near the intertidal zone.

Traditional inshore fisheries

The effect on inshore fish and fisheries will be of limited importance apart from possibly in shallow water areas and for fish with nursery areas in the intertidal zone. Traditional inshore fisheries may on the other hand be impacted through smothering of cages used for storing fish (herring, saithe), nets and other structures in the surface. Smothering of fishing gear and impeded fishing activity are also realistic to expect. Tainting is another potential hazard to inshore fisheries. After the "Amoco Cadiz" oil spill several species of wild fish (pollack, mackerel) and crabs (Cancer) caught at 30 m depth are reported to have been occasionally tainted. However, 7 weeks after the grounding fish and crustaceans were mainly free of taint in offshore waters and after 2.5 months this was also the case for all inshore areas except the innermost bays (Abers) (Chasse, 1978).

Harvest of seaweed and kelp

The potentially impacted coast south of Senja is one of the most intensively harvested areas of the coast for large subtidal kelp. Due to extensive overgrazing by sea urchins, the kelp has been wiped out over large areas of the bottom north of Senja, and harvesting in these areas have stopped. Harvesting of tidal seaweed, primarily knotted wrack (Ascophyllum nodosum), on the other hand, is performed along the whole of the coast of western and northern Norway, and in some areas this activity has significant economic importance.

Although long term oil pollution can cause reduced growth of weeds and kelp (Bokn 1985), this is thought to be due to chemical toxicity of oil. Reduced growth of the algal resources due to an oil spill is therefore not considered important. A more serious consequence of an oil spill is the smothering of knotted wrack in the tidal zone. Although the algae are expected to survive, and produce new clean growth, they are perennial and most of the plant will have a persistent cover of oil (Wikander 1982). This smothering will make the wrack unfit for harvesting. Recruitment of new wrack plants to an area is in general very slow, and since the annual growth is also small, we must expect at least around 10 years for an impacted area to recover completely for new harvesting.

5.4.6. Conclusion.

Intensive fish production systems are extremely vulnerable and more so than extensive systems, not primarily because of toxicity, but because of the effect of oil on fish behaviour in densely populated cages resulting in physical lesions to the fish. Reduced availability of oxygen caused by smothering of cages and increased oxygen demand caused by increased swimming avtivity also cause detrimental effects if oil reaches areas used for intensive production.

Pathological effects of oil can not be excluded, but will probably be a transient effect, mainly associated with species from shallow sheltered water where oil may accumulate and persist.

Effects of oil on traditional inshore fisheries are impossible to assess quantitatively, but is expected to be limited to disturbance of fishing activity.

Harvesting of kelp is not considered to be in jeopardy from an oil spill since they are taken subtidally, but harvesting of tidal seaweed may stop for several years in an impacted area since smothering either will kill the weeds or make them unfit for industrial use, and since the recruitment of new plants is very slow.

We conclude that in extensive fish production, traditional inshore fisheries, and mussel farms, tainting of fish and mussels is an effect which is probable, especially in mussels because of their filtering mechanism. Tainting is reversible and no effect will be seen after 1 week for salmon kept in clean water and up to 2.5 months for wild fish, crustaceans and mussels. Tainting of organisms in sheltered bays, where oil may persist for years, may probably continue for longer periods of time (years) if oil is not removed.

Smothering of fishing and aquaculture equipment is also likely to be an effect of an oil spill in the Heidrun field region. Cleaning operations may unintentionally increase the availability of hydrocarbons to the biota and redistribute the oil locally.

Aquaculture industry is located along almost the whole coastline in the four counties potentially affected by the Heidrun field development. For inshore fisheries and especially for aquaculture the most vulnerable part of the coastline is from Flatanger to Brønnøysund.

5.5 SENSITIVE SHORE/INSHORE HABITATS

5.5.1 Introduction

This chapter deals with the possible impact of the Heidrun development and activity on the ecological communities of the shoreline. The communities in question are those of the shallow water subtidal areas down to about 30 meters depth, the tidal zone, and the vegetational zone just above the sea (the "supralittoral zone"). Fish, seabirds and mammals are natural elements of some or all of these communities, but they are treated in separate chapters.

The appraisal will concentrate on the impact of oil drifting ashore from the heidrun field. We do not considered base activites or ship and helicopter traffic as a threat to these communities. One of the base localization alternatives implies construction of a supply base at Hummelvik (cf. Chapter 2), which will cause local physical alteration as well as disturbance during construction. Hommelvik has already substantial boat traffic and an increase in frequency of boats of 2-3 supply vessels a week (cf. chapter 2) will hardly cause any significant disturbance. Furthermore, on the assumption that localization of the supply base will be in Hummelvik proper, we do not expect that the supralittoral vegetation at Midtsandan NW of Hummelvik should be damaged. This area has conservation value on botanical and ornithological ground.

Other known discharges in the Heidrun area: production water, sewage, and drill mud on cuttings are not likely to affect the nearshore area.

5.5.2 Impact of oil on shoreline communities in general

Although it is claimed in many instances that every oil spill is unique, it is possible to outline a general chronology of a shoreline oil pollution incident. The overall effects are the same as those encountered during any other disturbance to a community: after exposure some or all the organisms die, and replacement occurs through a succession of opportunist species until diversity and dynamic stability are regained over a period of time.

Oil drifting ashore can in general affect the organisms by smothering and/or by toxicity, and will cause strong or small acute mortality in the inherent populations depending on a range of factors: type and amount of oil, type of community, season, duration of immediate smothering, etc.

Most data on shoreline oil pollution originates from investigations following nearshore spills such as tanker groundings or storage tank rupture. As outlined in Chapter 5.1 oil drifting ashore from the Heidrun field will in general have lost its toxic components by evaporation and dissolution before it reaches the coast. Experience from nearshore spills is therefore not strictly relevant in the assessment of immediate shoreline mortality in our context, but may be used as examples of worst case situations.

The main direct impact when oil from the Heidrun field strikes a shoreline will be through smothering. This will be most severe on communities in and above the tidal zone, less so in the subtidal zone.

The first impact phase will be followed by a depuration phase when oil is gradually lost from the shore system, either by cleanup procedures or natural processes such as erosion, dislodging, redistribution, biodegradation and photo-oxidation. The factors affecting the duration of the depuration phase are discussed in Chapter 5.2.

During the phase of oil removal or erosion longer term impact may occur. Oil trapped in crevices or sediment may leak small amounts of toxic components continuously to the environment, either from components in the oil or as products of photo- and biodegradation processes of less harmful hydrocarbons. This impact resembles a chronic oil or petrochemical discharge. If depuration is slow, with several years of low input of toxicants, this may lead to a gradual depletion of the receiving community, through sublethal effects on processes such as recruitment, growth and reproduction (Southward 1982). A persistent oily substrate may also physically prevent reestablishment of sessile organisms even though no apparent toxicity exists (Bakke 1986).

It is therefore likely that recovery of a shoreline community will be disturbed until the oil has disappeared or the remains have been deeply buried or turned into solid "inert" material such as an asphalt pavement. After that the recovery rate will depend on the rate of reestablishment of the keystone species of the community, which again is a function of supply of recruitment stages (larvae, spores, etc.) and generation turnover time.

5.5.3. Shoreline communities and sensitivity to oil impact

The impact of oil on a community is a function of sensitivity of the species present, and hence will vary with community structure for a given oil spill. Why some organisms are sensitive and others not, may have various explanations. Vulnerability may be linked to the route of entry of oil onto or into the organism, or to other stressors acting simultaneously on the species. Effects may also be indirect, mediated through changes in competition or predation.

Subtidal hard bottom communities

These are the communities on firm substrate (rock, boulders, concrete, wood, etc.) below the tidal zone. They are found as continuation of rocky headlands and shores, generally down to 10-40 meters depth where they meet with level sedimentary bottoms.

Within depths influenced by light, i.e. about 0-30 meters in the relevant coastal region, the communities are dominated by seesile macroalgae. The most conspicuous and canopy forming species are the large kelps Laminaria hyperborea, L. digitata and L. saccharina, and the fucoid seaweed Fucus serratus closer to the surface. As sessile understory species we find numerous red, brown, and green algae and typical animals are various species of sponges, sea anemones, hydroids, tube-worms, bryozoans and tunicates (sea squirts). Motile fauna on the substrate are winkles, dogwhelks, sea urchins, starfish, and among the fronds of seaweeds we find crustaceans (isopods and amphipods) and several species of fish, many being juvenile stages of fish normally found in deeper water or off shore.

Predation and competition for space are factors strongly influencing the structure of these communities. Seasonal changes are mainly characterized by strong growth of shortlived algae, many as epiphytes on other algae during the summer half of the year. The latitudinal change in community structure is small, but the change from the outer coast to the inner part of the fjords is more conspicuous as a response to change in water movement and fresh water input. Under similar hydrophysical conditions the subtidal hard bottom communities are roughly the same within the coastline in question. A frequent phenomenon recorded along the whole of the coastline is that large areas have been denuded of algae by the grazing effect of large populations of urchins. The ecological structure of the denuded areas seems to be very stable.

Little attention has been paid to the possible impact of oil spills on subtidal rocky bottoms. By definition these bottoms will not accumulate sedimented material, and the entry and persistence of oiled particles in these biotopes are therefore considered to be low and of short duration. Oil droplets in the water may be ingested by filter feeders, such as sponges, sea anemones, sea squirts, etc., but adverse effects of such ingestion during oil spills have not been reported. Experimental investigation have shown that corals (closely related to sea anemones, but tropical in this example), are remarkably resistant to unweathered dispersed oil. Concentrations of oil droplets up to 20 ppm gave only sublethal behavoural effects and recovery within 4 days (Knap & al. 1986). Furthermore, since it is expected that the concentrations of dissolved toxic components in the water when any Heidrun oil reaches the shore is very low, we conclude that the oil will have only small and short term impact, if at all, on these communities.

Ecosystem experiments have shown that chronic oil exposure may cause reduced tissue growth of macroalgae (Ascophyllum nodosum and Laminaria digitata) if the plants were exposed during the early phase of the growth season (Bokn 1985). One might therefore postulate that such effects could influence the harvesting of kelp for industrial purposes, which is an important activity along the coast. Since the effects were small, and found during long term exposure to a fresh diesel oil, with significant uptake of hydrocarbons in the tissues of the plants, we do not expect that a similar effect will be of significance from exposure to droplets of a weathered crude oil from Heidrun.

Subtidal soft bottom communities

A range of different types of sedimentary bottoms are found in shallow water along the coast. They range from coarse gravel and sand along the outer islands and in sounds with rapid water movement, to bottoms dominated by silt and clay in sheltered bays and fjords. The soft bottom communities host a range of organisms, mainly animals on or in the sediment. Dominant forms of feeding are ingestion of sedimentary material, filter feeding, and predation. The seasonal fluctuation is characterized by input of juvenile stages of the fauna after settling of larvae in spring to autumn and stabilization during winter. Settling intensity varies from one year to another, and this can cause dramatic changes in population densities especially of short lived species with prolonged freeswimming larval stages (cf. Mileikovsky 1971 with references). Community structure seems more influenced by sediment characteristics (e.g.,granulometry) than by larger predators such as fish and starfish (FoH 1984). As with subtidal hard bottoms, the change in community structure is more conspicuous when moving from exposed to sheltered areas (change in sediment features), and from shallow to deep bottoms, than when moving from north to south along the coast.

Several reports from accidental or experimental spills (e.g. Sergy 1985, Sanders & al. 1980, Boucher 1980, Hartog & Jacobs 1980, Grassle & al. 1981, FoH 1984) have shown that oil which accumulates in subtidal sediments can affect sediment communities. The effects are in general more subtle than in the littoral zone and expressed through species selective mortality, subnormal recruitment, reduced diversity, increased dominance, and prospering of opportunistic species, especially bristle worms. Massive immediate mortalities as recorded in the tidal zone during some spills have not been experienced. In the nearshore spill from "Amoco Cadiz", crustaceans, molluscs and burrowing sea urchins were the groups affected, some of them seriously, but most other organisms recorded showed little or no immediate reduction (Cabioch & al. 1980, Hartog & Jacobs 1980). Sediments heavily contaminated with oil in experiments have had negative effect on macrofauna recruitment in shallow water on the west coast of Norway, but not in the Oslofjord (FoH 1984). A proposed explanation is that the bottom fauna of the inner Oslofjord already is deprived of sensitive species due to eutrophication (ibid.).

Although our knowledge on effects of oil spills on subtidal soft bottoms is considerable, it has mainly emerged from studies of relatively fresh oil, where the influence of toxic components have been significant. Few data on effects of oil after long drifting time excist. Investigations after the most relevant spill: the "Dei Fovos" grounding off Helgeland, did not include subtidal recording (Wikander 1982). One report on subtidal effects of oil from the grounding of "Antonio Gramschi" which hit the archipelago of Åland in the Baltic Sea after 2 months drift showed no effects on macrofauna, and only small effects on meiofauna (Bonsdorff 1981), but it is hard extrapolate potential effects on corresponding communities on the western and northern Norwegian coast, since benthic fauna of the Baltic is far less diverse.

We do, however, expect that sedimentation of the weathered "Heidrun" oil to subtidal sedimentary bottoms, either directly or as eroded shore material, will have less direct effect than recorded after nearshore spills. The oily material may be ingested by sediment feeders, but will not necessarily affect these. Several years after the "Arrow" spill in Nova Scotia the lugworms (Arenicola marina), a typical detritus feeder, were more abundant in the oil contaminated sediments than elsewhere (Gordon & al. 1978). Also, the sediment feeding clam Macoma balthica was not apparently affected by the "Thesis" oil spill in the Baltic (Elmgren & al. 1980). Sediment bound hydrocarbons seem in general to be only moderately available to infauna (Anderson & al. 1979).

Although the evidence is sparse, we cannot rule out that subtle long term adverse effects from weathered oil in the sediments or from redistribution of old stranded oil may occur, and that this may cause a long lasting stress on the communities. The soft shell clam (Mya arenaria), a filter feeder, still showed subnormal growth and energy assimilation 6 years after the "Arrow" spill (Gilfillan and Vandermeulen 1978). It can also be postulated that even tiny amounts of oil in sediment may act as a negative signal to larvae which use chemosensory perception to find a suitable substrate during settling and thereby reduce recruitment. Such subtle long term effects may cause gradual diminishment of populations and decreasing diversity of the community. It is therefore expected that recovery will be delayed as a function of the persistence of oil in the sediment, but also that the effects will be small and detectable only where careful pre- and post-spill investigation is performed.

Rocky shore communities

This is definitely the most dominant type of tidal community along the impacted coast. Typical rocky shore communities are found on solid bedrock as well as shores with stable substrate of boulders and large stones. The communites are well known and described throughout northern Europe, and a thorough description will not be given here. They are characterized by two physical gradients of overwhelming importance: horizontally between wave exposure and shelter, and vertically between tide levels. Their populations are characterized by a relatively few ground-cover species such as algae, barnacles (primarily Balanus balanoides), mussels (Mytilus edulis), etc., grazers and predators such as limpets (Patella vulgata), periwinkles (Littorina sp.), and dog-whelks (Nucella lapillus), and a wide range of subordinate or opportunistic species whose presence often is dependent on the ground cover species.

The dominating organisms on most rocky shores of the impact zone, when wave exposure is less severe, are the foucoid algae, in particular knotted wrack (Ascophyllum nodosum) and bladder wrack (Fucus vesiculosus). These algae are long-lived and an Ascophyllum association is in general extremely stable, as long as no external force removes the wrack itself (e.g. ice scouring).

With increasing wave action the fucoid cover declines and is partly replaced by dense cover of barnacles, mussels and tufts of short cushion-formed algae.

Biological cycles are strongly seasonal with dense settlement and growth of larvae of e.g. barnacles and mussels, and of epiflora and -fauna during spring and summer, and a resting phase during winter when also some of the motile fauna may migrate into the subtidal to avoid freezing. Besides regular seasonal changes the community pattern of rocky shores is influenced by accidental processes. A typical feature of the northern part of the coast is the local destruction of the tidal zone biota by ice scouring during winter, especially in fjords influenced by freshwater runoff from rivers. On the outer skerries ice scouring is less frequent due to high salinity and rapid exchange of the surface water. Species selective impacts on a local scale can be caused by the predation by flocks of birds, and on a wider scale the effects of extremely warm summers or cold winters. Such impacts may lead to a chain reaction of changes in community structure for several years until the original dynamic structure is restored. The combined effect of physical influence, biological interaction and accidental events lead to the mosaic pattern of distribution of organisms which is characteristic for rocky shores along the coast.

As with subtidal communities, the horizontal change in rocky shore community structure is far less conspicuous when going from north to south along the coast than from the outer exposed shores to the sheltered shores of fjords and landlocked bays. Within the same wave exposure regime essentially the same communities are found along the whole of the coast in question.

The possible impact of the Heidrun oil on rocky shore communities may be regarded as one of several factors of disturbance which destabilizes the ecosystem and drives the community in the direction of monoculture (Southward 1982). The effect is normally species selective. Many organisms of the tidal zone resist dessication during low tide by closing up their shell or outer protection, e.g. mussels and barnacles, and they may survive short term oil smothering in the same way. Still they will be suffocated by thick layers of oil (Wikander 1982 and others). Mobile organisms, e.g., crustaceans and fish, may in some cases escape by seeking deeper water, but escape responses have also caused the animals to get stuck in the oil (Bonsdorff and Nelson 1981).

In general crustaceans have shown to be sensitive to oil spills (Hartog & Jacobs 1980, Teal & Howarth 1984). Amphipods are particularly vulnerable, possibly because oil will easily stick to the hydrophobic surface of their exoskeleton. Still, in many cases it is uncertain if the frequently reported persistent post-spill lack of amphipods has been due to mortality or to avoidance behaviour.

Macroalgae have been thought to be relatively resistant to oil smothering since oil does not adhere easily to their mucoid surface, but significant oil smothering and species-specific mortality of macroalgae in the rocky intertidal have been reported (e.g., Teal & Howarth 1984, Wikander 1982). In areas of heavy smothering of weathered oil from "Dei Fovos" at Helgeland all algal vegatation died and an initial recovery by green and brown algae was recorded after 2.5 years (Wikander 1982, Danielsen & al. 1985). In the lightly contaminated areas the smothered parts of the algae showed strongly retarded growth the subsequent spring, but new sprouts on the same plants were apparently healthy.

Based on spill experience, particularly from the "Dei Fovos", the hardy nature of the key organisms on the rocky shores, the recruitment potential that lies in larvae and spores distributed in the water, and the assumed lack of toxicity of the Heidrun oil when it reaches the shore, we expect the recovery potential of rocky intertidal communities along the coast to be strong as soon as the oil cover has disappeared. When the degree of smothering is small, or the self cleaning ability strong, normal recovery will probably start in a matter of weeks or months. Even before the oil is gone the contaminated areas may be invaded by grazers such as winkles and limpets which even seem to be able to graze away some of the remaining oil (Wikander 1982). Whether this has a deleterious effect on the animals concerned is uncertain, but it helps to clean the substrate for more vulnerable settlers.

The time necessary for full recovery will as stated earlier, be a function of time for oil removal, and in this respect rocky shores with boulders are considered somewhat more vulnerable than solid bedrock shores. Based on experience from the "Torrey Canyon" accident (Southward and Southward 1978), one may assume that rocky shore communites will recover in less than 10 years after the shore has become sufficiently clean for normal regrowth.

Tidal sediment communities

These communities are found on shores with transport and depositional substrates (cf chapter 2). They have in general a more reduced gradient than rocky shores and therefore constitute a much wider band between the high and low tide water level.

Soft bottom shores can be classified into:

gravel and coarse sand	(exposed)
fine sand	(exposed, sheltered)
mud	(sheltered)
eelgrass	(sheltered)
salt marsh	(sheltered)

With the exception of eelgrass and marsh areas sediment shores seem to have little animal and plant life. The vegetation is mostly microscopic consisting of unicellular or small filamentous algae attached to or interspersed between the mineral grains close to the surface. The fauna is also mainly found in the sediment either in interstitial spaces (meiofauna), or burrowing through the sediment (macrofauna). Most sedimentary shores also have small patches of rocky shore communities scattered around on boulders and rocks on the sediment.

The major soft bottom macrofauna groups are the molluscs, bristle worms and crustaceans (McLachlan 1983). An important element of the fauna are the mobile forms such as shrimps and fish (gobiids) moving in over the sediment at high tide to prey on other organisms, or birds moving in at low tide for the same purpose. In general the migration patterns found for motile soft shore fauna can be rather complex. It involves vertical migration in the sediment as well as horizontal movement along the shore and with depth, and tidal, diurnal, lunar and seasonal cycles may play a role (Ibid.).

The fauna and flora of sedimentary shores do not normally encounter the desiccation and extremes in temperature and salinity which rocky shore communities must endure, and are therefore considered to be less hardy. On the other hand life in sediment has its own stresses such as lack of oxygen in finegrained sheltered sediments, and the abrasive effects of sand grains at wave exposure. It is assumed that the community structure of sedimentary shores is more dependent on physical factors than biological interaction in contrast to rocky shores.

The only types of sedimentary shores where the macrovegetaion is conspicuous are the eelgrass beds and salt marshes. They may be regarded as different stages in the development of sheltered, level bottom, subtidal/tidal areas into supralittoral areas by mineral deposition. The eelgrass beds formerly covered vast areas of shallow water sedimentary bottoms, but after a parasitic disease in the grass species during the 1930es these communities were confined to small sheltered estuarine areas where the salinity is too low for the parasite?. The dominating structuring species are the sea grasses Zostera marina and Z. nana of which only the former extends into the tidal zone. Among their leaves and in the sediment below a rich and diverse community is found, primarily of animals such as snails, bristle worms, crustaceans, and fish. As silt tends to be deposited amongst the leaves and stems of the grass so that the bottom level rises, and as tidal influence becomes gradually less, the eelgrass beds are turned into salt marsh areas, where also other species of higher plants may grow.

Effects of oil on sedimentary shores have been reported from a range of accidental and experimental spills (Sergy 1985, Sanders & al. 1980, Farke & al. 1985, Kuiper & al. 1983 and many others). On exposed shores with gravel or sand oil may penetrate to considerable depth during low tide, but the flora and relatively immobile fauna of these shores is poor or lacking and the apparent effects on the shore itself therefore small. The motile fauna moving onto the shores at high tide is not expected to be seriously affected by the oil attached to the sediment, but may be smothered by oil lifted off the bottom by the water. The extent of such impact is considered small.

On sheltered sandy and muddy shores the effects can be more pronounced. In addition to initial species selective mortality, severe delayed mortality directly or indirectly as an effect of oil being buried in the sediment has been demonstrated (Kuiper & al. 1983). Such burial does not always occur, and in those cases the residence time of smaller spills may be short, i.e. a few months (Farke & al. 1985). Little direct penetration occurs when the sediments are saturated with water (Farke &. al 1985), but even then the bioturbative activity of animals such as lugworms (Arenicola marina) may bury oil to a significant extent (Kuiper & al. 1983). Buried oil may remain in the sediments for several years, depending on the conditions for biodegradation, primarily the availability of oxygen. Experiments (ibid.) have also demonstrated reduced bioturbative activity for weeks as an oil effect, and this may increase the possibility of oxygen deficiency in silty sediments. Heavy oiling of the sediment will add to this effect by inhibiting the gaseous exchange between the sediment and overlying water/air. In general one must therefore expect the impact of an oil spill on such communities to be long lasting, i.e. several years.

In eelgrass and marsh areas disappearance of the structuring grass species would cause complete collapse of the community. Effects of oil on eelgrass communites were studied after "Amoco Cadiz" (Hartog & Jacobs 1980). Here the eelgrass itself (Zostera marina) remained almost unaffected by the spill which occurred in April. Although leaf damage was recorded, this effect was short-term. Gastropods were also little affected by the spill. Brittle stars and crustacea of the groups Cumacea and Tanaidacea were affected, but recovered wthin a year, whereas the crustacean amphipods suffered long lasting severe reduction. The penetration of oil into the sediment was small, because the flatlying eelgrass leaves formed an almost impermeable mat between the slick and the bottom during low tide. This partly explained the selective effects on the fauna.

Salt marsh areas are in narrow definition tidal mudflats where the vegetation is predominantly higher plants (grasses). Salt marsh vegetation seem to survive single small spills with similar selective effects on the rest of the community as reported for eelgrass (Baker & al. 1977). The marsh grass may show deterioration of the plant parts above the ground, but in most cases the root system seems to survive, giving rapid regrowth. During larger oil spills, however, salt marsh vegetation may suffer heavy mortality and very slow recovery (Gundlach & al. 1982).

In our ranking of sensitivity of tidal communities we therefore rank sedimentary shores as more vulnerable than rocky shores, and among the former we regard mudflats and marsh areas as the most sensitive.

Supralittoral vegetation and fauna

Numerous spill incidents have shown that oil may be brought up on land above high tide level (e.g. for Norway: Wikander 1982, Falk-Petersen & al. 1983). Hence the vegetational zone, especially above wind and wave exposed shores, is likely to be impacted. These communites are found scattered along the whole of the coast, mainly as continuation of similar substrates in the tidal zone. The main types of substrates are:

Saltmarshes, mainly found in the inner end of the fjords associated with larger river outlets, and also as result of post-glacal landrising turning silty and muddy tidal areas into marshland. These have been treated above.

Sandy shores and dune areas. Coarse sand areas are most frequent in inner part of wave exposed bays. Fine sand areas and dunes occur in open parts of the coast. They are in general exposed to waves and wind.

Gravel and boulders. They generally occur in wave exposed areas where the substrate slopes more steeply towards the sea.

Seaweed banks, which are also found on exposed coast where detached seaweeds collect above the surf zone.

A range of different supralittoral communities have been defined on the Norwegian coast based on the dominating species of vegetation (Holten & al. 1986). The plants of these communities can tolerate salt infested soil to a varying extent (halophytes). Some are obligate halophytes, e.g. glassworth (*Salicornia europaea*) and species of *Atriplex*. Some are facultative halophytes which may grow in other places, but are frequent on the shore possibly due to lack of competition there, e.g. marram grass (*Ammophila arenaria*) and scurvy grass (*Cochlearia officinalis*). Other members of these communities are indiffent as to location. Several species have their northern limit of occurrence in Trøndelag and Nordland, but the most important gradient in species composition within the impact zone goes from the outer coastline to the inner end of the fjords (Holten & al. 1986). Seasonality is typical for land vegetation with a summer growth and flowering season and a winter resting season. The soil fauna of the supralittoral communities is not very diverse and is dominated by small forms such as the collembolans (small arthropods closely related to insects) and nematodes (roundworms).

Oil can cause damage to terrestrial plants in different ways: by toxicity, smothering and by changing soil properties. The effect of oil on individual plants have been recorded from accidental and experimental spills, and in general oiled plants recover only by new growth (Baker 1971, Wikander 1982, Klokk 1986).

Individuals of annual plants will normally die after being smothered (Baker 1971) and the population will not recover unless colonized by new seeds. Experiments have further shown that weathered oil may cause reduced or retarded germination of seeds (Danielsen & al. 1985) and recolonization in annual plants is therefore more dependent on oil removal than in perennials.

Perennials recover by regrowth from the root system or from budding and may show normal new growth even if large amounts of oil are still present (Wikander 1982, Falk-Petersen & al. 1983). If oiling occurs during the winter season, these plants appear to be very little affected (Danielsen & al. 1985). If oiling occurs during the summer season flowering and seed production may be impaired (Baker 1971), but this has limited effect on perennials as the dominating growth is vegetative. The most severe effect is found when the root system or overwintering organ of the plant has been exposed (Baker 1971), either because oil has penetrated into the soil or because the root system is very shallow.

Effects of oil on soil microfauna have been recorded in experimental spills of weathered oil (Danielsen & al. 1985, and references therein). The results showed more pronounced effects in collembola than in nematods. The former group did not recover within an experimental time of one year, the latter showed an immediate drastic reduction in density, but also a rapid recovery predominantly by species that feed on bacteria. The difference in response in these major groups was tied to differences in microhabitat: nematodes are aquatic organisms and live in a film of water in the soil. They would therefore be predominantly affected by the water soluble components of the oil. It is in this example interesting to note that products of photooxidation, which one must assume was produced, did not have any apparent effects on nematodes, even though these compounds are considered both to be toxic and water soluble. Collemboles are terrestrial, and it was assumed that the persistent effect of oiling on these was physical, caused by smothering of the respiratory surfaces (trachea) of the animals.

We have not found any scientific ranking of the shoreline plant communities as to oil sensitivity. One can, however, infer form the literature available that the most likely communities to be impacted are those of the outer coast (Holten & al. 1986), both because the oil is likely to strike first and most severely here (Wikander 1982), and because wind and waves are stronger and therefore more likely to transport oil onto land. Furthermore it is apparent that oiling during late spring, summer and early autumn will cause most damage, because of severe effects on annual plants. Still in the spill incidents along the coast of western and northern Norway where the effects on vegetation have been recorded (Wikander 1982, Falk-Petersen & al.

1983, Danielsen & al. 1985, vedlegg 5.1.), the recovery was rapid. These communities were found on gravel and boulder substrate. Similar experience from oil pollution of supralittoral vegetation on exposed sandy shores along the coast does not excist. On such shores, however, the vegetation is normally separated from the sea by a relatively wide band of clean sand and one may postulate that the harsh storm situation necessary to transport the oil onto the vegetation also will lead to considerable dispersal of the oil in the water column before the shore is reached, which again will reduce the amount of oil on land.

We therefore assume that the supralittoral vegetation in general is not susceptible to severe oil damage, in some areas because the oil is less likely to strike the vegetation, or when this happens because of their ability to recover rapidly. In dune areas we postulate that the impact of traffic by man and machinery used in cleanup of the sand will contribute more to dune erosion than any oil that is deposited on the dunes.

5.5.4 Assessment of sensitive shorelines in the impact zone.

Based on the considerations given above, and the discussion in Chapter 5.2 on residence time and self cleaning ability, the shoreline communities can be ranked in the following way considering how vulnerable they are assumed to be to oil drifting ashore from the Heidrun field:

Type of community		vulnerability
	hard bottoms	very low
subtidal	soft bottoms	low/medium
	eelgrass	low/medium
	bedrock shores	low
	boulder/stone shores	medium
tidal	gravelly shores	medium
	sandy shores	high
	mudflats	very high
	marshes	very high
supralittoral	sand dunes	medium
	mixed sand/gravel	medium

Distribution of the main stretches of sandy and muddy shores, shores with boulders and stones, and bedrock shores have been discussed in Chapter 5.2 (cf. Figures 5.2.1 to 5.2.3). The main distribution of the most vulnerable communities: the tidal flats (sandflats, mudflats and marshes), are given in Figures 5.5.1 to 5.5.3, based on the SINTEF sensitivity maps. The SINTEF maps do not distinguish clearly between these three types of tidal flats, all being important e.g. as feeding grounds for birds. Some of the areas on the outer coast are typical sand/gravel flats interspersed among islands and skerries, those of the fjords are more of mixed sandy, muddy and marshland type.

Figures 5.5.1 to 5.5.3 also show main locations of supralittoral vegetation communities and the areas of particular conservation value are identified. The basis for producing distribution maps for subtidal communities does not exist.

County of Nordland (Fig. 5.5.1 and 5.5.2)

Tidal flat communities are found scattered along the whole of the coast, especially in the Lofoten-Vesterålen area. On the coast of Helgeland and east of Vestfjorden they are more scarce, but several locations occur between Nesna and Brønnøy. Many of the areas, which are important feeding grounds for birds lie on the open coast, in shelter among numerous skerries. Although the sediment of the open coast tidal flats in general is sand or gravel, they are particularly vulnerable since these are the first areas to be hit by the oil, and since it is not likely that one can protect these areas with any success. The tidal flats in the inner part of Vestfjorden (Hamarøy and Lødingen) are less likely to be damaged since, according to the oil drift model, smothering of the inner part of Vestfjorden is less likely to occur. The few tidal flats recorded in the narrow fjords and land locked bays in the county, should also be feasible to protect from receiving oil.

Supralittoral vegetation of any significance is sparse in the county. Highest occurrence is in the Vesterålen region and around Herøy-Alstadhaug. A few of the valuable locations, especially at the coast of Helgeland, are exposed. These are therefore likely to be contaminated by oil in heavy weather.

As discussed in Chapter 5.2 the most important stretches of sandy shore communities are found at Andøya and Sømna, but this type of community is also scattered along the whole of the outer coast of the county.

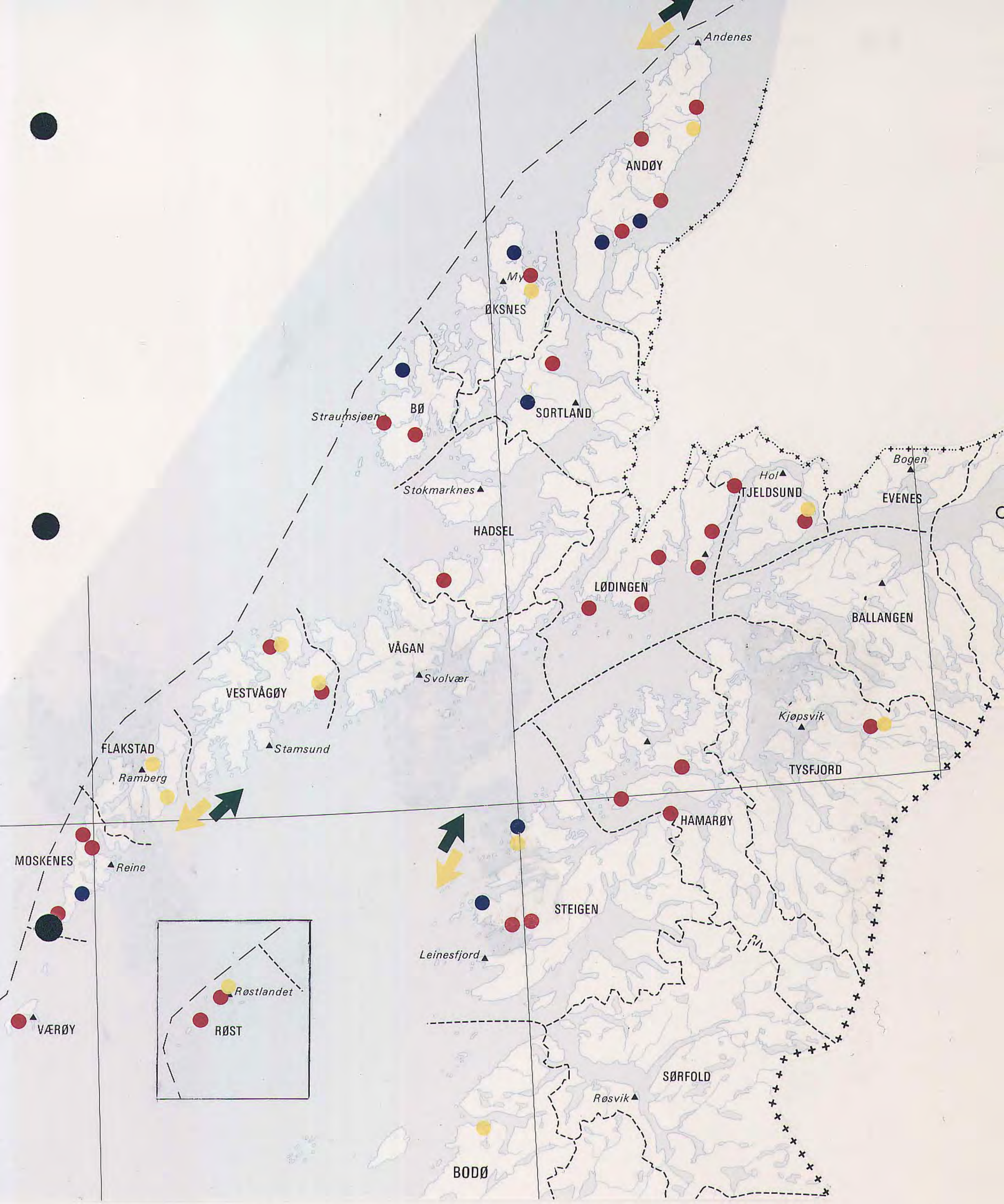


Figure 5.5.1 Map of the Nordland county north of Bodø indicating distribution of sensitive shoreline communities.

● : tidal flats, ● : supralittoral vegetation of high value,

● : other areas of supralittoral vegetation

Impact zones: ➡ ⬅ high, ➡ ⬅ medium, ➡ ⬅ low.

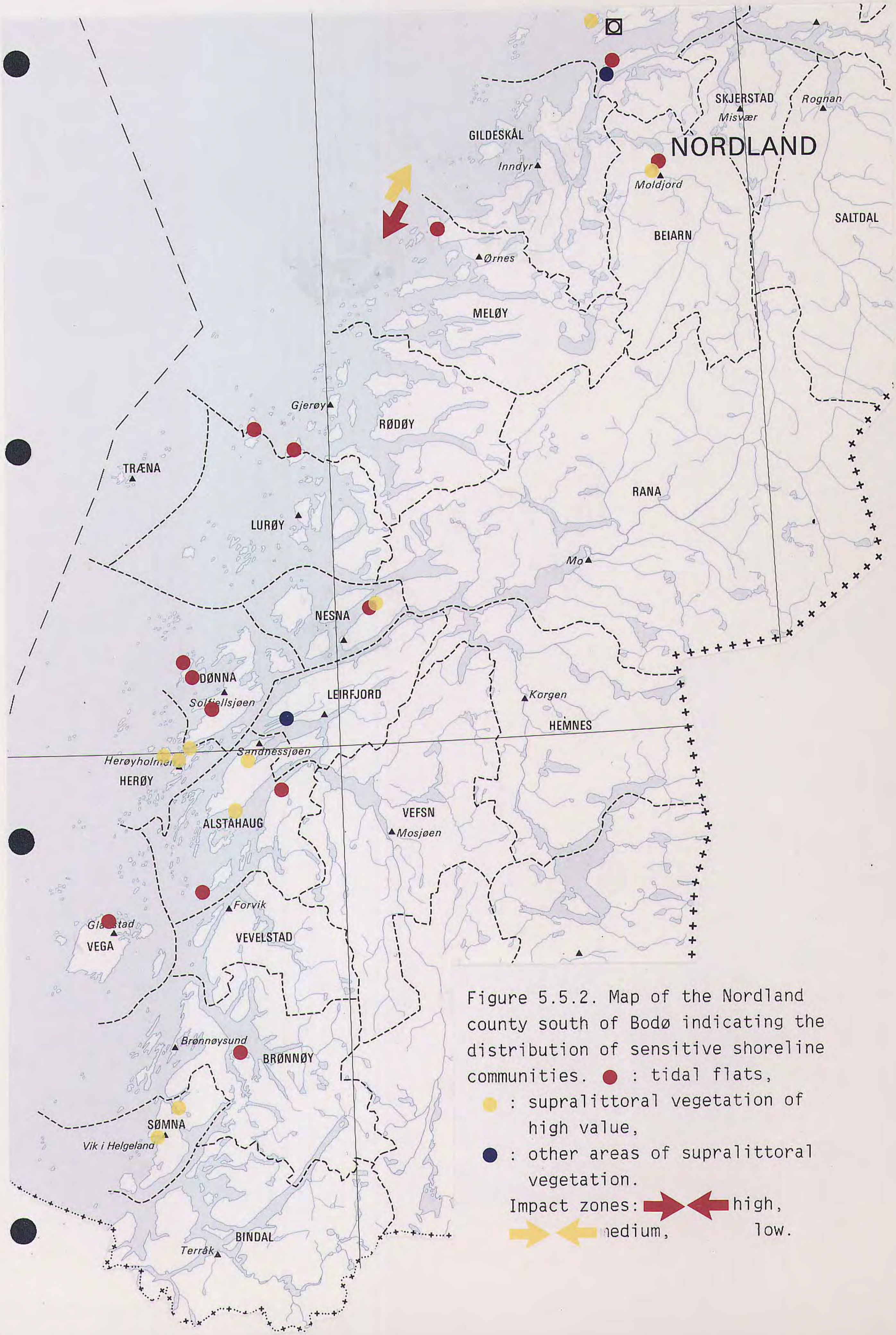


Figure 5.5.2. Map of the Nordland county south of Bodø indicating the distribution of sensitive shoreline communities. ● : tidal flats, ● : supralittoral vegetation of high value, ● : other areas of supralittoral vegetation.
Impact zones: high, nedium, low.

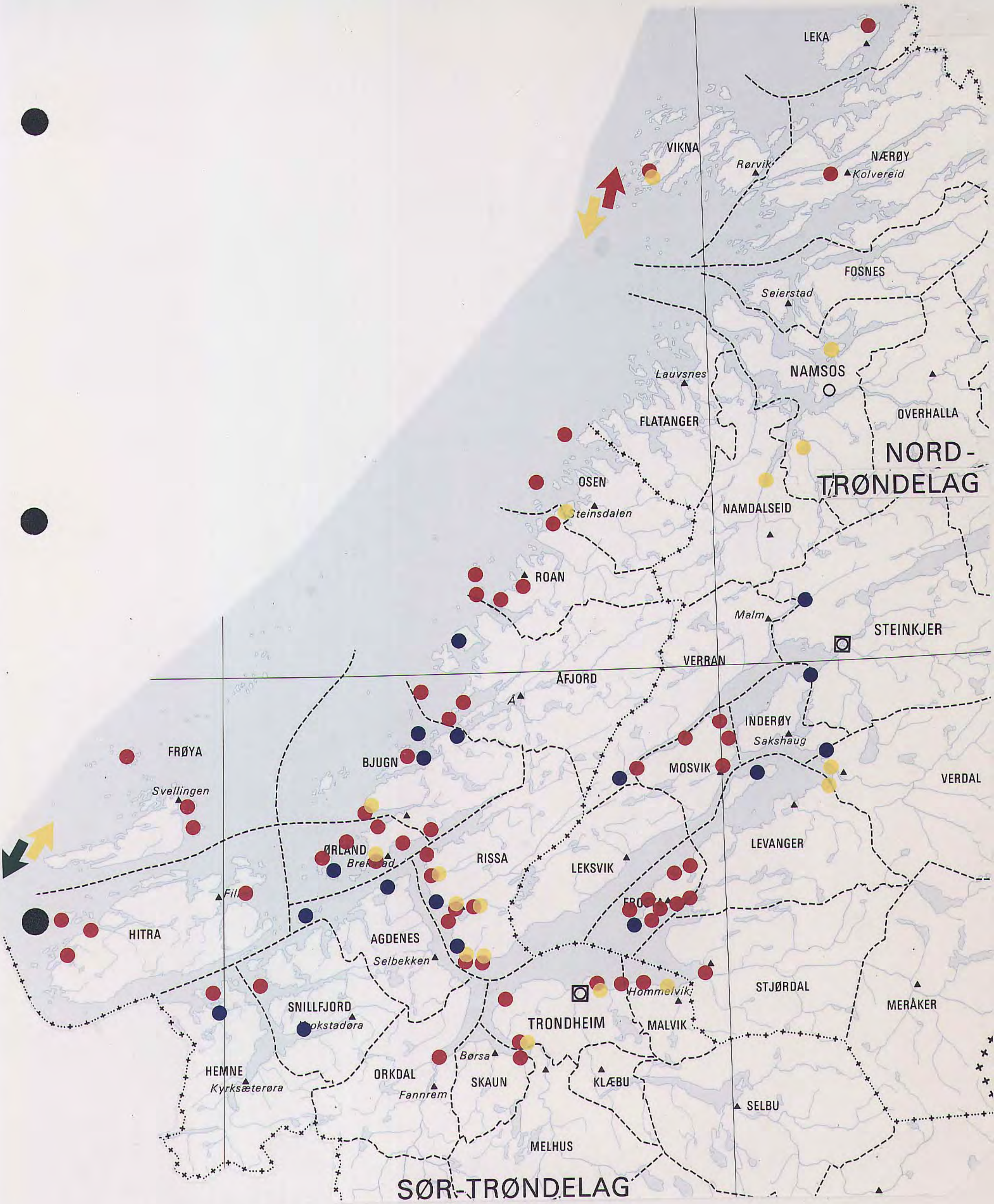


Figure 5.5.3 Map of the Nord- and Sør-Trøndelag counties indicating distribution of sensitive shoreline communities.
●: tidal flats, ●: supralittoral vegetation of high value,
●: other areas of supralittoral vegetation
Impact zones: ➡ ⬅ high, ➡ ⬅ medium, ➡ ⬅ low.

Counties of Nord- and Sør-Trøndelag (Figure 5.5.3)

On the open coast of Nord-Trøndelag county there are very few tidal flats. Some areas are found at Leka and Vikna. In contrast the open coast of Sør-Trøndelag has a high number of tidal flat communites in smaller bays and among the skerries. This section of the open coast is therefore considered to be particularly sensitive to an oil spill.

The most extensive occurrence of tidal flats in the impact coast from Heidrun is found in Trondheimsfjord. They dominate the shores of Ørland, Rissa, and Froan municipalities, and are frequent along the inner part of the fjord. In addition to their ecological significance several of these are valued for research and educational purposes.

The most frequent occurrence of supralittoral vegetation in the counties is also in the Trondheimsfjord, especially the middle and outer part, but the reduced wave action in this region renders these communities less vulnerable to an oil spill than the supralittoral communities on the open coast around and north of the entrance to the fjord. Some important areas of supralittoral vegetation are localized around Namsos, but these are also sheltered and hence less likely to be smothered by oil.

As was discussed in chapter 5.2 the most extensive areas of sandy shores were found in the middle and outer Trondheimsfjord, in Bjugn municipality, and around Namsos. In addition to the tidal flats shown in Figure 5.5.3, muddy shores are distributed along most of the east coast of Trondheimsfjord (Figure 5.2.3).

5.5.5 Conclusions

Although the dominating types of shoreline communities on the coast of potential impact from an oil spill at Heidrun: rocky shores, subtidal rocky substrates and subtidal communities on sand, shellsand, and gravel are considered to be relativly resistant to long term severe damage by oil pollution, sensitive communities are found scattered along the whole of the coast.

In the high impact zone sensitive communites are especially sparse, but the region Alstadhaug, Herøy, Dønna should be given slight priority as being most sensitive, because of the occurrence of tidal flats and valued supralittoral vegetation. This region has already experienced one major spill, from the "Dei Fovos", and there is evidence to assume that a medium size spill will result in a period of public concern about the shore status for about 5-10 years in the region. Obviously, oil will still remain in the communities after that, with possible sublethal effects on the biota, but we assume that the detection of such persistent effects will demand careful scientific investigation.

In the northern medium impact zone the Lofoten, Vesterålen, Andøya coastline is considered most vulnerable. Mudflats, and sandy shores are common along this coast, and oil which beaches, will remain for a long time, more or less buried in the sediments. The possibility of secondary long lasting pollution is therefore great.

In the southern medium impact zone an oil spill will cause most damage to shore communites if it beaches south of Flatanger, mainly because of the high occurrence of tidal flats where oil will accumulate and cause secondary long term contamination. A particular concern is given to the possibility and consequence of oil entering the Trondheimsfjord, with the largest extent of sedimentary shores of the whole of the impact region. A significant oil spill entering the fjord would probably cause severe and long lasting impact on the tidal communites, and since most of the land around the fjord is densely populated, the public concern will be large. One must however stress that, according to the drift model presented in Chapter 4, the entrance to the fjord is not strictly within the medium impact zone, and in winter and spring the drift trajectories suggest that the entrance also is outside the low impact zone. Statistically, therefore, the possibility that a major oil spill from the Heidrun field will drift into the Trondhjemsfjord is present, but the probability that this will happen is small.

SEABIRD RESOURCES IN THE INFLUENCE AREA
OF HEIDRUN OIL FIELD AT HALTENBANKEN

Report to CONOCO Norway Inc.

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Trondheim September 1987

5.6 SEABIRD POPULATIONS

5.6.1 Introduction

Species included in this report

The category seabird includes species which depend on the sea for the bulk of their nutrient resources (see Folkestad 1979). These species fall naturally into two major groups according to their chosen lifestyle; typical or seasonal seabirds. Typical seabirds comprise the largest and most important group in Norway, and are restricted to marine areas on a year-round basis. They include the following species: fulmars, gannets, cormorants and shags, auks, most seagulls and some marine ducks. Seasonal seabirds including divers, grebes, several duck species and some gulls usually breed near freshwater, but rely on the sea during the remainder of the year.

In this report, greatest emphasis is placed on species which are vulnerable to oil contamination, and these are categorized and ranked according to the following criteria:

- vulnerability to oil contamination
- population size of vulnerable species
- congregations of birds during critical periods
- localities particularly exposed to oil contamination from oil fields, e.g. outlying coastal archipelagoes and skerries.

It is stressed that certain species and localities are discussed here on the basis of criteria associated with an oil spill situation. Large numbers and concentrations of seabird species also merit evaluation in association with other problems.

Annual life cycle of seabirds

Abundance and distribution of seabirds vary seasonally. Some species, which breed in large concentrations, later spread out over larger geographical areas. Other species which have a scattered breeding pattern, congregate in large flocks during migration, while moulting, and/or throughout the winter.

The following table provides a rough outline of the most important periods in the annual life-cycle of seabirds:

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Okst.	Nov.	Des.
Breeding				-----	-----	-----	-----	-----	-----			
Post breeding movements by auks							-----	-----	-----			
Moulting duck species						-----	-----	-----	-----			
Migration/rest areas			-----	-----	-----		-----	-----	-----	-----	-----	
Wintering	-----	-----	-----								-----	-----
Open sea	-----	-----	-----	-----			-----	-----	-----	-----	-----	-----

Breeding season

Typical seabirds, as most of the cliff nesting birds, may occur in large concentrations of hundreds of thousands or even millions of individuals within a restricted area. In contrast other species are more scattered along the coast, while other species breeds inland far away from the sea in individual pairs or small colonies.

The breeding season varies in time among seabirds as among other birdgroups, and it is thus not possible to give any exact outline of the duration of this period. For example, Puffins appear to breed relatively early and may lay their eggs in April, but the Storm Petrel (Hydrobatidae) on the other hand, breed relatively late and lay their eggs in August/September.

An even more complicating factor in a description of the breeding season, is a period of colony attendance prior to egglaying. This is a regular feature of the breeding biology of several seabirds, but the duration of this period may vary to a great ectent among the species. For ecample, in some auk species birds may begin to return to their breeding sites about 3-4 months before egglaying, and even 6 months is known in the Guillemot (Nettleslip and Birkhead 1985).

Post breeding movements by auks

Following a period of twenty days confined to the nest, young Razorbills and Guillemots, which are as yet incapable of flying, jump into the sea accompanied by one of their parents. Together they embark on a swimming migration to wintering areas.

On the Norwegian coast, young birds may leave the colony as early as July in Western Norway, and somewhat later (August) in northern Norway. The actual point in time, and the series of events associated with jumping were investigated in colonies at Runde by Fylkesmannen i Møre og Romsdal (1985).

Adult birds start moulting abruptly and lose all of their primary feathers simultaneously. This temporary loss of flight ability is compensated by complete renewal of feathers later. The entire moulting process usually lasts about 45-50 days (Birkhead & Taylor 1976). Young birds are able to fly at about the same time as adults. Throughout this period, young are fed by their parents, and the actual point in time when young become independent is unknown. It is assumed that they are gradually weaned throughout the autumn and winter, probably before adult birds return to their breeding colonies.

The density, direction and dispersal of these swimming movements are poorly investigated. We have little relevant information about seabirds on the Norwegian continental shelf south of Troms, as only a few seabird studies have been conducted at open sea in this area.

Consideration of the post breeding movements of auks away from their colonies, is critical to evaluation of the impact of major oil spills or less serious leakages of a more chronic nature associated with oil installations. These movements are therefore treated separate, although the data is very poor for coastal areas of Norway.

Moulting

Waterfowl renew all of their wingfeathers simultaneously, during the course of a 3-4 week period between June and September. The actual point in time varies from species to species, and with the sex and age of individual birds. Waterfowl are incapable of flying during moulting, and form large flocks often in exposed areas of the skerries of the outer archipelago. Flocks of moulting waterfowl are therefore very vulnerable to oil spill at this time.

The four main species moulting in the survey area moult at different times, and it has been difficult to cover the actual moulting period for each species throughout the entire survey area. Results therefore represent minimum numbers of birds, especially Greylag Geese and Red-breasted Mergansers.

Migration/wetlands

The distribution pattern of seabirds during the breeding season when they are largely confined to land, is often very different from that which they exhibit during the rest of the year. Typical cliff nesting birds, which may occur in large concentrations a restricted area in the breeding season, may occur more or less spread out over large areas at other times of the year. For other species, a contrasting situation is common, where individual pairs or small colonies may congregate in dense concentrations after the end of the breeding season.

The extent to which different seabird species wander in search of food outside the breeding season is also variable. Knowledge of these movements may be critical for evaluations of which seabird populations may be affected by the occurrence of an oil slick in a given area. The extent of our present knowledge is largely confined to ringed birds.

Recent studies of biometric data, some on oil contaminated birds, have increased our knowledge of population composition. However, more information is needed about which populations occur along our coast.

The outline given in the section of the species accounts, roughly discusses our current knowledge of migrations and seabird distribution during the winter, and should not be regarded as an adequate description of the migrations of these species.

Wetlands are often important for species other than typical seabirds, and large numbers of species often exploit such localities. They are also often areas which contain unusual biotopes which should be protected. Localities associated with marine habitat are emphasized. Freshwater areas are not included, even when freezing of these areas during winter may force birds into nearby shoreline habitat where they may be exposed to oil contamination.

Several wetland areas are protected, or have been proposed included under regulation for environmental protection. Some seabird areas are already protected, including the following: Runde at Herøy (MR), Froan at Frøya (ST), Grandfjæra at Ørland (ST), and Røst (NL). Data from several localities are given in discussions of each species, under comments on breeding, moulting and/or wintering.

Winter

When interpreting the results, one must acknowledge that some of the limitations of this material have resulted from varying coverage of some geographical areas, methodological problems, and that in many cases results only represent a temporary situation when large areas were only investigated on one single occasion.

Open sea

There is little available data on seabirds at open sea in areas of the Norwegian sector which may be affected by oil contamination from the Heidrun field. Limited information has been collected through some studies conducted on swimming movements of auk species originating from colonies which may be affected by oil spill from Heidrun: Runde, Røst, and colonies in the British Isles and on the Faroe Islands.

Comprehensive seabird mapping at open sea has been accomplished in Great Britain. Data from these investigations are only superficially treated in this report, and then only in association with the Razorbill and Guillemot swimming migration.

Typical seabirds such as the Fulmar, Gannet, Kittiwake, Guillemot, Brünnichs Guillemot, Razorbill, Puffin and Little Auk, mainly winter on the open sea. Some concentrations have been found near land, and are probably the result of unusually rich sources of food in these areas. Mapping of these species at sea should be undertaken, before the consequences of an oil spill can be fully understood.

5.6.2 Seabirds and oil

"Seabirds, of all marine organisms, suffer the most from effects of oil pollution." GESAMP 1978, ref. by Gray and Brattegard (1979).

Seabird ecology

Characteristic of all typical seabirds is their low rate of reproduction. Compared to most terrestrial birds it takes a long time, often 3 to 7 years, before the birds become sexually mature. In most cases the female produces only one egg per year. This low reproductive rate coincides with a low natural mortality of the adults, which may live to a relatively old age. In such a situation a slight increase in mortality of the birds, e.g. by oil pollution may greatly affect the size of the population.

Seabird Vulnerability to Contamination by Oil

When the plumage of a seabird is contaminated by oil, it no longer serves an insulating function and many birds thereby freeze to death. Birds may also suffer internal damages through ingestion of oil in their food, or while preening soiled plumage. Several factors determine species vulnerability to oil contamination, among them the following:

Behaviour. Several species exhibit pronounced social behaviour, and therefore occur in large concentrations within a limited area. In such cases, even relatively small oil leakages may affect considerable numbers of birds. Species which are largely confined to the surface of the sea during winter (or night time), are particularly exposed. There is a continual risk for considerable losses of colonially breeding species like auks and cormorants, as long as large numbers of these birds congregate on the sea in the vicinity of colonies.

Season. Because wintering seabirds spend most of their time on the water during predominantly dark periods where chances for discovering an oil slick are minimal, they are more directly threatened by contamination. An oil slick at sea may be especially dangerous prior to the start of the breeding season, when tens of thousands of seabirds congregate on the water in the vicinity of breeding cliffs.

Diet. Seabird species which graze on land to a large extent, are not as subject to oil contamination of their plumage or reduced access to nutrient resources as species which are entirely dependent upon the sea.

Population status. The impact of oil contamination will be greater for species which are few in number, or which are affected by several other negative factors.

Recovery periods. There are considerable differences in the lengths of time required to restore a population to normal levels following extensive oil damage. The reproductive capacity of auks is extremely limited, and great losses of sexually mature birds will result in severe consequences for the population.

Today, seabirds are commonly divided into three groups according to their vulnerability/susceptibility to oil contamination:

extremely vulnerable
vulnerable
less vulnerable

Divers, grebes, marine ducks and auks are considered extremely vulnerable. In association with a project financed by the OED (AKUP), the Directorate for Nature Management developed guidelines for environmental impact analyses on oil/seabirds to be carried out prior to the opening of new exploration drilling fields. These guidelines include more detailed indexes of vulnerability (Anker-Nilssen 1987).

Critical oil spill situations

Folkestad (1983) has summarized the following critical situations in the event of an oil spill:

* concentrations of flightless birds
  - moulting grounds/moulting flocks
  - post breeding movements of auks, and areas with large numbers of young birds.

* roosting areas

* periods with poor light conditions at night, and particularly during winter in northern areas.

In addition, in the event of an oil spill, vulnerability is increased in all areas where birds are concentrated at grazing localities, breeding grounds, and during migration.

5.6.3 Material and methods

Data base

A review of the work on mapping of seabirds in Norway is given by Follestad (1986).

Information about seabird distribution is compiled on the basis of data stored by the Seabird Project (Directorate for Nature Management, Reaserch Division). Data concerning the area discussed in this report has been obtained from several sources. These include projects carried out under the auspices of the Directorate for Nature Management, the Royal Ministry of Environment, the Environmental Conservation Division of Fylkesmannen i Møre og Romsdal, the Norwegian Ornithological Society, and some private persons.

Little is known about spring migrations, but occasional observations indicate that large concentrations of divers, grebes and ducks are found in certain coastal areas from the end of March until the beginning of May. However, these occurrences are not indicated on maps because the available information is deficient and may easily present a completely distorted picture of the actual situation.

Information about seabird roosting places is lacking. We do know that some species congregate in large and dense flocks at night, but these flocks have not been mapped to any large extent. This type of mapping is time consuming and expensive, but should be conducted for the most important seabird wintering localities.

Some of the material presented here has only been briefly analysed, and results should therefore be regarded as preliminary.

Evaluation of the data base

Møre og Romsdal County
Breeding - material based on investigations over a period of several years, regarded as good. Meanwhile, som material from the 1970's on Eider and some other species, resulted from unsatisfactory methods.
Moulting - surveys carried out in 1985, considered good but with inadequate coverage of mergansers.
Winter - comprehensive material from several years, but structured such that comparisons with data sets representative for seabird populations are difficult.

Sør-Trøndelag County
Breeding - most of the data for several species is from the 1970's but very accurate numbers are available for Cormorants in recent years. Current estimates on Eider and Black Guillemot are probably too low, and are based on insufficient information.
Moulting - personal surveys conducted in 1985 and 1986. Adequate datas for several species, but little information on Red-breasted Merganser during the moulting period.
Winter - the entire county was investigated in 1985-1986, and with the exception of a few extremely exposed areas, statistics are adequate.

Nord-TrØndelag County
Breeding - most of the data was collected after 1980, and much of the material on many species is considered good, excluding that on Black Guillemot.
Moulting - personal surveys conducted in 1985. Good data on Eider, uncertain for Velvet Scoter. Surveys began too late for Red-breasted Merganser, and too early for Greylag Geese.
Winter - personal surveys conducted in 1984 and 1986. Good data, but lacking for some outlying areas including some localities in Ytter Vikna.

Nordland County
Breeding - most of the data was collected after 1980. The data on several species, particularly cormorants, is good. Data on Greylag Geese, Eider and Black Guillemot is poor.
Moulting - personal surveys conducted in 1985, and several years at Vega. Data on Eider is good, but less accurate for Velvet Scoter. Surveys were started too early to include Red-breasted Merganser, and too late for Greylag Geese, apart from the population living on Vega. Little data from areas north of Træna.
Winter - personal surveys conducted between 1983 and 1986. Good data from several areas. Data is particularly lacking in outlying exposed areas with extensive shallows. There are few counting stations in these areas. Information for some areas varies considerably from year to year.

Open sea
Open sea areas are extremely poorly investigated, and data is only available from a few occasional excursions.

Methods for Counting Seabirds

Breeding

Most counts are carried out according to standard methods for mapping breeding seabrids (Nordic Minister Council 1983). The majority of the field work is conducted in June and July, and yields material of varying quality, which is often determined by when in the breeding cycle each individual species is most effectively appraised. Data on Greylag Geese, Eider and Red-breasted Mergansers is generally poor because these species should usually be counted in early May. Estimates on the numbers of individuals at the large bird colonies at Runde, Lovunden and RØst are also poor.

Moulting

Most counts were made from the shore, but boats were used to transport several field workers to suitable observation posts on land. Areas in the vicinity of these posts were scanned with telescopes and bionculars. Some counts were also made from boats. Some sections of each area were surveyed from a helicopter, and our experiences with theis technique were very positive (Follestad et al. 1986).

Moulting ducks are very shy, and often quickly vanish when observed from a boat. Therefore field work was restricted to periods of good weather and tranquil seas, when large flocks could be relatively accurately counted from the shore.

Winter

Counts were largely carried out using standard methods for mapping seabirds during winter (Statens Naturvårdverk 1978, Nordic Minister Council 1983). The sea is thoroughly scanned with a telescope or binoculars from chosen observation posts. Helicopters were used in some areas in 1986, to transport field workers to counting localities and to cover areas which were impossible to observe from land. Experiences with this method were very positive, and we highly recommend the use of helicopters in future mapping projects.

The distribution of the sexes within a given population was established by discriminating between "adult males" and "adult females and young". Further divisions were possible for some species, but are time consuming and are not a regular part of inventories. Only a few individuals were aged in the field for species such as swans and gulls.

Some species were difficult to distinguish from each other, and were often classified as "unidentified diver/s" "Great Northern/-White-billed Diver", or "unidentified cormorants". Combined results are presented for several species in order to reduce the numbers of maps and tables.

Open sea

Counts are made from a boat or plane using standard methods. Observations are recorded in ten minute intervals and density calculations are made on the basis of positions plotted on squares of unlimited sizes. Squares of 20 x 20 km (400 km^2) were used in this investigation.

Inaccurate Sources

When studying the results and conclusions presented int this report, one must also consider the weaknesses and limitations of the data included. Please refer to Follestad et al. (1986) for a more detailed discussion. In many cases, results presented here should be regarded as representing minimum statistics.

Data Treatment and Map Projection

All mapping data was plotted on coded charts and stored in the data bank of the Seabird Project at the Research Division (Follestad and Nygård 1984, Follestad 1986). Counting zones and observation posts are recorded on a map which is kept at the Game Research Division, and which assures that future counts will be based on corresponding subdivisions of localities.

Distribution maps are drawn using the Seabird Project's mapping program SUPERMAP (Kvenild and Strand 1984). Data is thereby easily accessible for later up-dating, future use in impact analyses, and to assist planning of protective measures in critical oil spill situations.

When several counts of wintering seabirds are made in one area, only the results of the most recent observations in a given area are referred to in this report. Only one count has been made in most areas.

Winter data from Møre og Romsdal has been treated in a special manner, as different locality subdivisions have been used from year to year in some areas. Statistics represented on municipality maps are based on data arranged in 1 x 1 km squares. The data program summarizes the total of individuals in each square for each month, every year. Average monthly numbers are calculated for each square, and the highest resulting figures from the months between December and March, are combined with the averages.

Fylkesmannen i Møre og Romsdal (1985) has combined the maximum numbers of individuals per locality in periods between December and February. This method may exaggerate statistics on species which wander, or which occur in varying numbers from place to place, or from year to year. We have chosen average calculations in order to obtain data which is more readily comparable with figures from other counties. March data has also been included in our calculations because only data from that month is available for some counties farther north. In certain situations this may have resulted in that only courting aggregations of some species are represented, and that average calcultions may yield higher than maximum numbers. Comparisons of the results of these different methods are given for some species in Table 5.6.1.

Winter data from Vega are also treated separately, because count areas were slightly different from year to year in certain regions (Follestad et al. 1986).

Different symbol ranking is used for each species or group of species represented on the map. A ranking factor is provided in SUPERMAP and is used to construct the diameter of symbols. For comparable species of similar abundance, equivalent ranking factors are used to obtain the same drawing on several maps. In most cases, diameter is proportional to the number of birds registered, but diameter may also be constant on a few maps. When comparing maps of birds with low numbers like grebes and divers with those of more abundant species like Cormorant and Eider, one should be aware of ranking factor differences which are intended to provide the best possible visual projection of observations.

Further research and monitoring

In order to fully understand the long term consequences of oil pollution for seabird populations, increased knowledge about the population dynamics of each species is essential. Therefore basic biological research is vital to analyses of the impact of oil pollution on seabirds.

This report hopefully provides a foundation on which to build further research and establish monitoring programs, which will be useful in interpreting problems encountered as a result of developments within the petroleum industry. We wish to emphasize that the population composition of several species should be thoroughly investigated, and that ringing is vital to this type of research.

Table 5.6.1 Comparison of two methods for calculating population estimates for three groups of wintering seabirds in Møre og Romsdal County, (refer to the text). Method 1 = Maximum number for each locality from December to February. Method 2 = Maximum average for one month, December to March.

Municipality	Divers 1	Divers 2	Grebes 1	Grebes 2	Cormorants 1	Cormorants 2
11 Vanylven	1	1	3	4	300	561
14 Sande	20	23	110	122	1150	1325
15 Herøy	4	4	20	15	950	481
16 Ulstein	18	7	20	9	2700	2500
17 Hareid	2	1			93	38
19 Volda	1	1			11	10
20 Ørsta					5	4
31 Sula			12	9	55	30
04 Ålesund	1		1		340	302
32 Giske	30	21	73	85	700	305
34 Haram	27	16	27	23	630	680
45 Midsund	33	54	86	184	660	742
02 Molde	5	5	8	8	200	109
46 Sandøy	50	45	250	113	3900	1970
47 Aukra	18	12	180	244	960	1267
48 Fræna	24	7	54	31	2350	1010
51 Eide	2	3	16	4	170	71
54 Averøy	11	8	13	15	3800	3000
56 Frei	2	3	15	17	92	82
57 Gjemnes					13	12
60 Tingvoll	1	1			4	4
03 Kristiansund	3	2	5	4	360	106
69 Aure	7	12	35	38	42	210
72 Tustna	2		9	7	46	32
73 Smøla	350	267	700	518	7200	4679
Total (ca.)	610	500	1640	1450	26700	19600

Chronic oil pollution, which to a certain extent is always associated with drilling activities and the petroleum industry in general, can result in damages to seabirds. Investigations of the extent of this type of pollution should be initiated.

Enormous seabird resources would be exposed to oil contamination in the event that an oil spill stranded in the influence area. Research and development of methods for preventing seabirds from coming into contact with oil on the surface of the sea, should be given priority.

5.6.4 Seabirds within the influence area

Breeding season

Between 2 and 3 million pairs of seabirds annually breed along the coast of Norway, representing breeding populations comparable of size with that of Great Britain, Ireland and Iceland (Røv et al. 1984). A sentral data base has been established throughout the Norwegian Seabird Project (1979-1984), and most of the Norwegian coast have now been investigated. Much of the data however, dates back over several years, and is of varying quality. In addition several different census techniques have been employed in varying breeding seasons. In spite of the fact that the data base is still incomplete, there is fairly good basis for making population estimates for most species.

Colonies of cliffbreeding seabirds within the influence area for Heidrun and estimates on the number of the most vulnerable species to contamination from oil spills, are shown in fig. 5.6.1 (from Røv 1984).

Moulting waterfowl

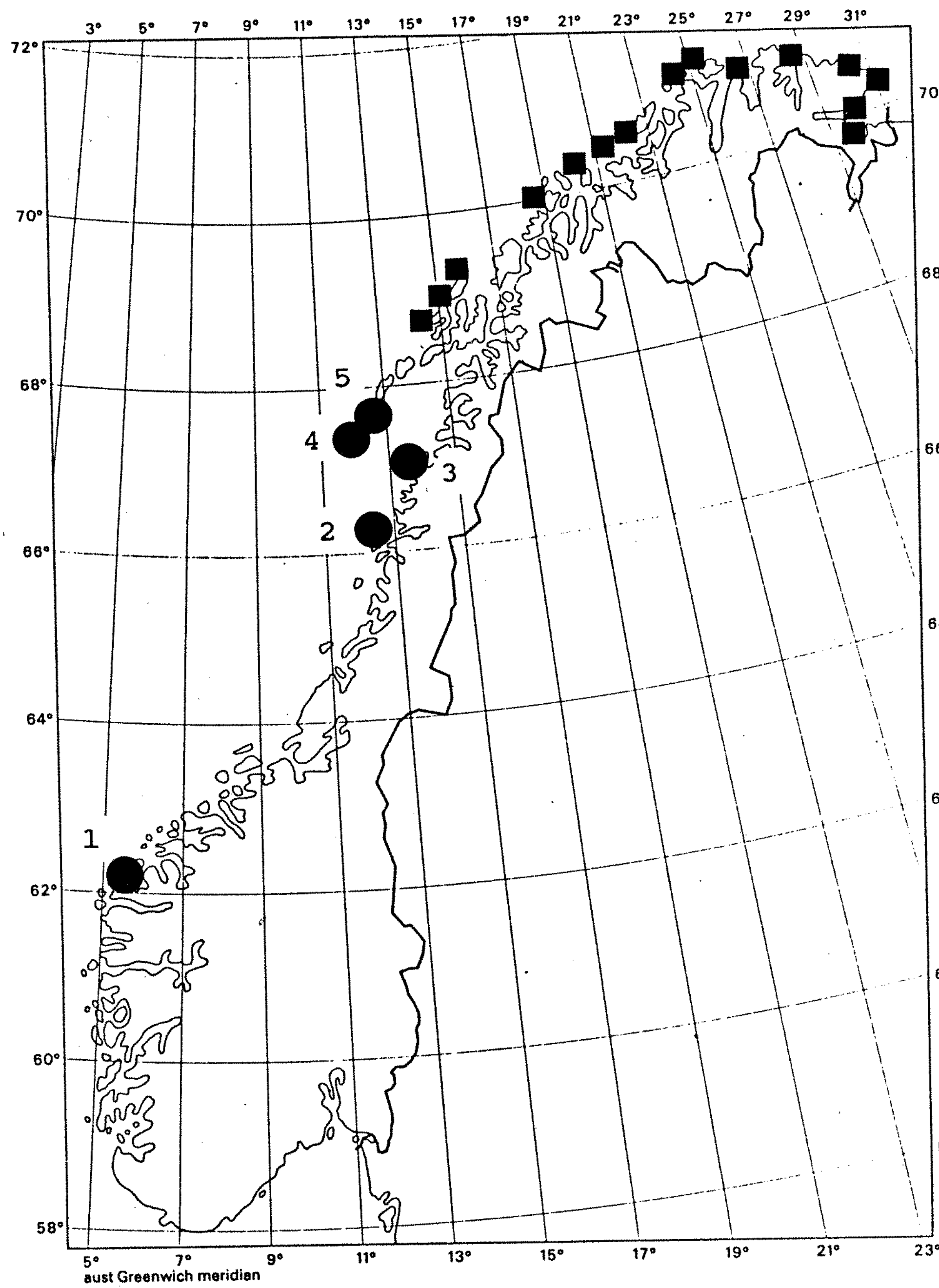
Estimates on numbers of moulting waterfowl were made for the entire coastal area from Møre og Romsdal, to Træna in Nordland county in 1985. Most of this material is summarized by Follestad et al. (1985). Some, more recent data on moulting Red-breasted Merganser and Greylag Geese, has become available after the publication of the above mentioned summary.

Tables 5.6.2 and 5.6.3 present our current knowledge on the status of moulting duck populations in the influence area of the Heidrun field.

A more detailed description of the situation regarding moulting waterfowl is provided for Froan, which supports the largest demonstrated concentrations of Eider in Norway. Only extremely sparse data is available on moulting waterfowl in areas from Træna to Vestfjord.

Tab. 5.6.2 The number of moulting waterfowl per county. All figures are rounded off.

County	Greylag Goose	Eider	Velvet Scoter	Red-breasted Merganser
Møre og Romsdal	900	13000	550	1300
Sør-Trøndelag	6700	52500	8700	4750
Nord-Trøndelag	1900	7500	260	750
Nordland (south)	8800	24000	1600	2800
Total	18300	97000	11000	9600



Colony	Kittiwake	Razorbill	Guillemot	Puffin
1. Runde	60.000	3.200	10.000	75.000
2. Lovunden				60.000
3. Fugløy				10.000
4. Røst	23.000	4.000	4.000	700.000
5. Værøy	19.000	800	2.000	70.000

Fig. 5.6.1 Large birdcliffs (●) that directly or indirectly can be influenced by an oilspill from Heidrun. Other large birdcliffs in Northern Norway, with more than 10.000 breeding pairs of seabirds, is also shown (■). (from Røv 1984). The numbers given must be considered as rough estimates.

Tab. 5.6.3 The number of moulting waterfowl from Møre og Romsdal to Nordland (southern parts) arranged by municipality. Figures for Greylag Geese and Red-breasted Merganser are up-dated relative to Follestad et al. (1986).

Municipality	Greylag Goose	Eider	Velvet Scoter	Red-breasted Merganser
Møre og Romsdal				
Sande		180		
Herøy		750		
Ulstein		520		
Ålesund		225		
Giske		900		55
Haram		1565	30	
Sandøy		750		430
Aukra		2250	25	110
Fræna		2010		
Eide		30		
Averøy		240		60
Kristiansund		505		
Sunndal		165		
Surnadal		60		
Smøla	860	2500	500	650
Sør-Trøndelag				
Hitra	175	2065	690	655
Frøya	5200	36000	520	3350
Ørland	20	6715	7235	290
Bjugn	620	6815	140	300
Åfjord	365	690	100	130
Roan	275	70		
Osen	25	200		
Nord-Trøndelag				
Namsos	20	820		
Fosnes	35	470		
Flatanger	40	475		
Vikna	1000	4035	260	690
Nærøy	30	900		30
Leka	475	560		
Nordland				
Bindal	340	900	1	
Sømna	1250	1215		2000
Brønnøy	200	1315	130	690
Vega	6000	12000	1440	360
Herøy	495	820	1	95
Dønna	140	1595		280
Lurøy	335	4895		
Træna	60	1280		50

Winter

The Norwegian coast is an important wintering area for many seabirds, and for several species it holds a significant part of the European population. Counting of seabirds in Norway, during winters of rough sea conditions, low tempreature and short daylight is difficult. Thus is our existing information on wintering seabirds mainly based on single counts, and variations in the numbers from year to year may bias our conclusions. For further comments, see Follestad et al. (1986).

Table 5.6.4 present our current knowledge on the status of populations of wintering seabirds in the influence area of Heidrun. Data from Møre og Romsdal are from Nygård et al. (in manus), the rest from Follestad et al. (1986). A more detailed presentation including other species, is given in Follestad et al. (1986) and Fylkesmannen i Møre og Romsdal (1985).

Tab 5.6.4 The number of wintering seabirds in the influence area of Heidrun summarized per county. All figures are rounded off.

Species or groups of species	Møre og Romsdal	Sør-Trøndelag	Nord-Trøndelag	Nordland (south)
Divers	600	575	400	600
Grebes	1.650	650	180	300
Cormorants	19.000	18.000	4.000	9.000
Eider	25.000	40.000	15.000	60.000
King Eider	100	750	1.000	4.200
Velvet Scoter	500	7.100	1.200	3.100
Long-tailed Duck	8.000	8.000	2.500	8.400
Red-Breasted Merg.	6.000	3.000	1.100	2.100
Black Guillemot	2.000	5.000	1.500	4.700

Migration based on ring recoveries

The data base for this section is partially based on a coarse analysis of results on ringed seabirds retrieved (Fylkesmannen i Møre og Romsdal 1985). This material includes finds of birds ringed in Sogn og Fjordane, Møre og Romsdal and Sør-Trøndelag counties (here referred to as central Norway), and results are summarized in Tab. 5.6.5.

Although these findings are discussed in association with Møre I field, they are included here because they provide the only recent data on which species are found in the influence area outside the breeding season.

Tab. 5.6.5 a. Recoveries of ringed seabirds in central Norway (Sogn og Fjordane, Møre og Romsdal and Sør-Trøndelag) according to where they are found.

Species	Northern Norway		Central Norway		Southern Norway		Other Countries	
	Entire year	Nov.-Feb.	Entire year	Nov.-Feb.	Entire year	Nov.-Feb.	Entire year	Nov.-Feb.
Gannet	1		1				2	
Cormorant	1		16	6	8	4	16	4
Greylag Goose			8				10	4
Eider	1		26	3				
Guillemot	62	46	36	19	43	32	11	9
Razorbill			2		5		7	4
Black Guillemot			30	4	1			
Puffin	3	1	8				8	6

Tab. 5.6.5 b. Recoveries of ringed seabirds in central Norway (Sogn og Fjordane, Møre og Romsdal and Sør-Trøndelag) according to where they are ringed.

Species	Northern Norway		Central Norway		Southern Norway		Other Countries	
	Entire year	Nov.-Feb.	Entire year	Nov.-Feb.	Entire year	Nov.-Feb.	Entire year	Nov.-Feb.
Gannet			1				3	1
Cormorant	139	49	16	6			1	
Greylag Goose	16		8		2		1	
Eider	13	4	26	3				
Guillemot	17	13	36	19			97	51
Razorbill	6	3	2				25	2
Black Guillemot	2	2	30	4				
Puffin	9	5	8				4	1

5.6.5 Important seabird localities

Runde, Lovunden and Røst/Værøy are the three largest cliffbreeding colonies which may directly or indirectly be affected by an oil spill from Heidrun. Impact analyses and mobilization of protective measures in the event of an oil spill, are primarily calculated on the basis of an oil spill during the breeding season for these populations.

As may be expected considering the large Shag colony at Runde, Sande, Herøy and Ulstein in Summnøre support large winter populations of Shags. The outlaying coast of Runde was not investigated during the winter, and actual figures are probably much higher than those registered. Relatively high numbers of grebes and divers have also been registered at Sande and Ulstein.

Giske and Haram support significant populations of divers, grebes and cormorants. Relatively large numbers of Red-breasted Merganser have been registered on Giske, and good populations of other marine ducks have been observed in both municipalities.

Outer coastal areas of Romsdal are important for several species. Large numbers of divers, grebes, cormorants and Red-breasted Merganser have been registered in the municipalities Midsund, Sandøy, Aukra and Fræna, as well as significant populations of Eider, Long-tailed Ducks and Velvet Scoter. A large population of Whooper swans is also found in the Fræna/Eide area.

Good populations of cormorants and Red-breasted Mergansers have been registered in the vicinity of Averøya.

Smøla is clearly the most important wintering area on the coast of Nordmøre. Significant numbers of several species have been registered here, especially populations of divers and grebes, which are among the largest in the country. The Red-throated Diver and the Great Northern Diver are predominant among divers, while the Whitebilled Diver is relatively scarce in this area.

Smøla is an important moulting area for Greylag Goose, Eiders and Velvet Scoters. The populations of wintering divers and Red-necked Grebes are significant in Europe.

Froan and Vega are two of the most important breeding areas for Black Guillemots in Norway, and an oil spill here may have drastic consequences for the entire population of this species.

The breeding populations of Cormorant and Eider are also outstanding. Froan and Vega may be the most important moulting sites in Norway for Greylag Goose and Eider, with about 35.000 Eiders in Froan, and also the most important wintering areas for several species. Froan and Vega are two of the most important seabird areas in Norway.

Ørlandet is an important moulting area for Velvet Scoter and Eider, and a wintering area for several species. The wetlands of Ørlandet is unique in this region, and is an important area for several dabbling ducks and waders. Some localities are protected according to the Ramsar convension.

Ytter-Vikna is an important wintering site for several species.

Sklinna is an important breeding area for Cormorants, Shags and Puffins.

The coast of Helgeland south of Vega has important moulting and wintering areas for several species.

5.6.6 The species account

Maps that covers the entire influence area and county distribution maps from Møre og Romsdal to Lofoten, are enclosed in a map appendix. Maps are drawn for the most vulnerable species to oil contamination.

DIVERS Gavia sp.

This group includes two species breeding in Norway, the Red-throated Diver and the Black-throated Diver, and to high arctic breeders, the Great Northern Diver and the White-billed Diver.

Breeding

The Red-throated Diver is the most abundant and widespread diver species, and breeds regularly up to the coast of Helgeland. It may here search for food at sea in the vicinity of their breeding localities, and they could thus possibly be affected by contamination from an oil spill in the breeding season. It is however uncertain if this will happen in such an extent to influence the population development on a long time scale.

Neither the Great Northern Diver nor the White-billed Diver are breeding in Norway. The breeding population of the Great Northern Diver at Island, is estimated to about 500 pairs (RSPB and ICBP 1981), but is a more common species in Greenland and North-America.

The White-billed Diver is everywhere present in apparent low numbers.

Winter

The Red-throated Diver winters regularly in the influence area of Heidrun, north to the coast of Helgeland. The most important winter sites are Smøla, Hitra, Frøya and Vega.

The Black-throated Diver migrates out of the country, and only single individuals winter along the Norwegian coast.

The Great Northern Diver winters regularly in the influence area of Heidrun. The most important winter sites are Smøla, Ørlandet and Storfosna, Tarva in Bjugn, Linesøya in Åfjord, Bispøyan in Hitra, outer parts of Vikna and Vega.

The White-billed Diver winter in Europe only regularly in Norway, where it is found most commonly from Sør-Trøndelag and northwards. This species is often found in other localities than the Great Northern Diver, but the reason to this is unknown.

These species are usually solitary, dive frequently, and are difficult to observe on the water. Results therefore represent minimum numbers.

GREBES *Podiceps sp*

This group includes mainly two species, the Slavonian Grebe and the Red-necked Grebe.

Breeding

The Slavonian Grebe breeds inland, and the population size in Norway is estimated to about 500 pairs (Fjeldså 1973).

The Red-necked Grebe breeds among others in Sweden and Finland, and it is thought to be birds from these populations that winter along the Norwegian coast (see Follestad et al. 1986).

Winter

The Red-necked Grebe is the most numerous Grebe during the winter. The influence area of Heidrun holds about 90% of the Norwegian winter population of this speceis, estimated to 2.700 individuals by Nygård et al. (in manus). Smøla is the most important winter site, with about 300 individuals. Other important winter sites are Bispøyan in Hitra, Ørlandet og Storfosna in Ørland, Outer Vikna and Vega.

The Slavonian Grebe is a less numerous species in winter, but about 80% of the Norwegian winter population of about 800 individuals (Nygård et al. in manus), winter within the influence area of Heidrun.

GANNET *Sula bassana*

Breeding

Gannets breed at Runde which supports the largest concentration of this species in Norway (Røv 1984).

Migration

Four ringed Gannets from Runde were recovered in northern Norway, at Runde, in the Netherlands and in Germany. Three foreign Gannets (two British and one Icelandic) were found in the investigation area. These recoveries demonstrate that Gannets wander along the coast of northern Europe and at open sea, but we are unable to provide more detailed information on their migration patterns.

Young Gannets are fed by their adults until they leave the colony. The newly fledged juvenile swims away from the colony. It cannot, for a week or two, raise itself from the surface, mainly because it has too much fat. Also, its wings are not quite fully grown.

During this period young Gannets are vulnerable to contamination from oil spills. However, as the main migration route probably is south-wards, they are unlikely to be threathened by any oilspill from Heidrun.

As the Gannet population has increased in later years, losses of young Gannets one year, is not thought to affect the population development at Runde at a long time scale.

CORMORANT *Phalacrocorax carbo*

Breeding

The most important breeding areas for Cormorants are primarily located in the outer archipelago in Trøndelag and the coast of Helgeland (Tab. 5.6.6). Over 70% of the entire cormorant population in Norway breeds within the influence area for Heidrun field. Population numbers have increased between 1980 and 1985. Recent population figures indicate approximately 21,000 breeding pairs of cormorants in Norway today. Estimates are very accurate and are based on surveys of nests in colonies or aerial photographs.

Cormorants breed in dense colonies of up to several hundred pairs, and these are often located on small islands and skerries which are exposed to weather and wind. Cormorants are sensitive to disturbance during the breeding season, and rapidly abandon their colony when humans approach. This may result in enormous losses of eggs and young, which are then plundered or killed by gulls living near the colony.

Many Cormorants migrate out of the country during the autumn.

Cormorants spend much of their day at resting or roosting stations, and are therefore considered less vulnerable to oil contamination than many other seabird species. Meanwhile, they may become susceptible if they are driven off the skerries and out into an oil slick, as for example during the night.

Table 5.6.6 Geographical distribution of the breeding population of Cormorants in Norway around 1985 (Røv and Strann 1987).

Area	Year	Number of pairs
Sula	1986	680
Froan	1986	3000
Vikna	1985	1820
Sklinna	1985	1100
Sør-Helgeland	1985	2300
Vega	1985	3000
Nord-Helgeland	1985	1600
Træna-Myken	1982-85	1250
Salten	1982	125
Vestfjorden	1982-85	350
Mosken	1985	85
Lofoten, nord	1985	450
Vesterålen	1983-85	600
Andøya	1983	200
Troms	1982-83	145
Vest-Finnmark	1983-84	1800
Øst-Finnmark	1981-85	2650
Total, rounded off		21000

Migration/Winter

Outside the breeding season, Cormorants are common along the entire coast of southern and central Norway. Ringing recoveries indicate that a large proportion of the population migrates south, to some extent also out of the country (Fig. 5.6.2). Several birds recovered in central Norway, were originally ringed in northern Norway. Most recoveries were made in September-October, although there are several for the winter period from November to February. The material suggest that the influence area is an important wintering area for some segments of the North Norwegian Cormorant population.

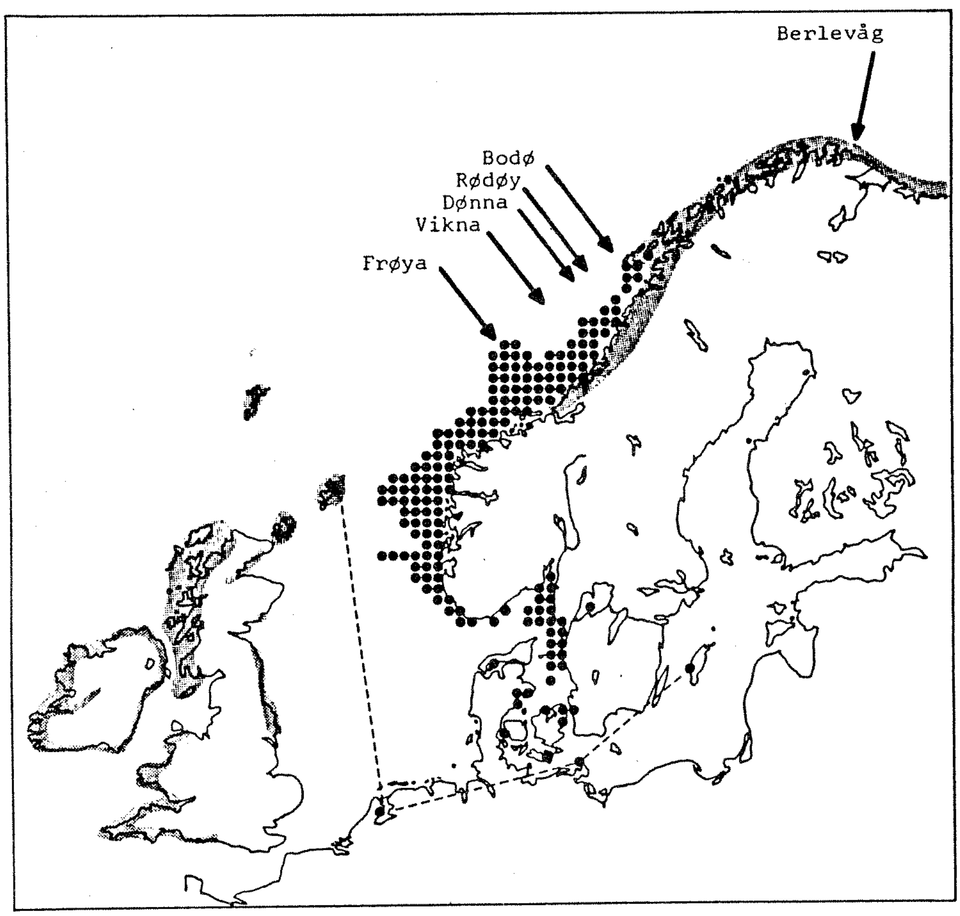


Fig. 5.6.2 Recoveries of Cormorants ringed in Norway. The distribution of Cormorants Phalacrocorax c. carbo in north-western Europe is indicated by hatched lines. Ringing localities are indicated by arrows and approximate recovery localities are indicated by circles. The geographical limits of the recovery area are indicated by the dotted line (after Røstad 1982).

SHAG *Phalacrocorax aristotelis*

Breeding

A significant breeding population of Shags is found in the influence area. The most important Shag breeding area is in Sunnmøre, and the colony at Runde is one of the largest in Norway. A significant population decline has occurred after 1975 (Folkestad 1981).

There is also a considerable breeding population at Froan, which includes several smaller colonies. This population has remained stable during recent years.

Sklinna is another important area where Shags breed on scree slopes and in the breakwater at Heimøya. If an oil slick drifted toward Sklinna, the harbour area and the breakwater may function as a kind of trap, collecting oil in the vicinity of these colonies.

Concentrations of Shags is also breeding at several localities in Vega and Rødøy.

Shag nests are much more concealed than those of Cormorants. They are often located under boulders and in rocky crevices, and are therefore less frequently disturbed.

Only a few, if any, Norwegian Shags migrate out of the country during the autumn. Today the most concentrated wintering grounds appear to be located in outer coastal areas of Nord-Møre and Sør-Trøndelag, where Shags from Sunnmøre, Trøndelag and Nordlang congregate.

Shags spend part of the day at resting places, and are therefore considered less vulnerable to oil contamination than many other marine seabird species.

Migration/Winter

More than 20% of all Shags which are ringed, are recovered, and recovery material for this species is more extensive than for any other seabird species in Norway, because this species is often hunted or drowned in fishing tackle.

The winter population on the coast of Sunnmøre and Romsdal, is mainly comprised of birds from the colonies at Sunnmøre. The coast of Nord-Møre and Trøndelag south of Trondheimsfjord, is a major wintering area for Shags from Sunnmøre, and colonies from northern Norway (Johansen 1975).

Winter populations found along the coast north of Trondheimsfjord, appear to originate from colonies in northern Norway. All recoveries in Norway of Shags from foreign populations, have been made south of Stad. Therefore all Shags found in the influence area of the Heidrun field probably are from Norwegian populations.

Shags from Runde winter in areas between Trondheimsfjord and Sognefjord. Recovery material suggests that on this coastal stretch, large concentrations of wintering Shags are found near Smøla, Hitra and Frøya, and these areas are regarded as the most important Shag wintering sites in Norway.

The wintering area of the population at Runde appears to have been displaced northward the 1950's simultaneous with serious declines in the herring population.

The principal midwinter consentrations of Shags, and in smaller numbers, Cormortants, are the archipelagos of Smøla, Hitra and Frøya. Of the total winter population of cormorants in these municipalities, as well as the influence area as a whole, Shags makes up about 70 %. The Cormorant prefer shallow inshore water, and are rarely found far out at sea, as may to a greater extent be the case with the Shag.

GREYLAG GOOSE Anser anser

Breeding

Greylag Geese breed along the coast from Vestlandet to as far north as Finnmark. The greatest numbers are found in Møre og Romsdal, Trøndelag and the coast of Helgeland. After the turn of the century, the population sharply declined, but has increased more recently (Folkestad 1978).

Because data is lacking, there are no maps of breeding populations of Greylag Geese. Froan and Vega are two important breeding areas. There are also several smaller areas with good breeding populations within the area currently under discussion.

Previous population estimates on breeding Greylag Geese in Frøya municipality were between 50 and 100 pairs (Frengen & Røv 1978, Lorentsen & Bangjord 1984). Results from 1985 indicated that the population on Frøya was significantly greater than suggested by previous estimates. Although these estimates were encumbered by a certain degreee of inaccuracy in that not all of the area was investigated, the breeding population of Greylag Geese on Frøya now appears to have approached 350-450 pairs. Comparison of these figures emphasizes the need for more accurate investigations of coastal populations of Greylags, also in order to gain more information about the large numbers of moulting Greylags found in the area.

Although Greylag Geese are less vulnerable to oil contamination than many other species during most of the year, they are particularly exposed during moulting.

Moulting

The most important moulting areas for Greylags, are Frøya including Froan Nature Reserve, and the Helgeland coast including the island of Vega. A significant population of Greylag Geese would be threatened if an oil spill struck the coast near Froan or Vega during the moulting period.

In Frøya the moulting population of Greylag Geese is about 5.200 individuals, and in Vega about 6000. This is with our present knowledge far more birds than could be recruited from local breeding populations of Greylags in these areas. The moulting population is probably mainly comprised of Norwegian birds, but may also include geese from other countries.

Smøla is an important moulting area for Greylag Geese in Møre og Romsdal county, and in 1985 and 1986, the population was about 860 individuals. This population mainly lives in the southwestern part of the Smøla archipelago. It is not known whether this moulting population is recruited from local breeding populations (Nord Møre), or represents an aggregation of moulting birds from other areas.

The population at Vikna, Sør-Helgeland stands out as considerably larger than was indicated by a helicopter survey on July 24, 1985 (Follestad et al. 1986). Meanwhile, population estimates of about 1,000 individuals are based on relatively old statistics and the present size of the population is not known with certainty.

Data for Sør-Helgeland is supplemented by data from 1982, which indicates that areas south of Vega are important Greylag Goose moulting areas. This emphasizes the importance of carrying out surveys at appropriate times of the year, and in some areas, also the need for supplementary mapping of moulting Greylag Geese.

Migration

Until 1985, eighteen recoveries have been made of geese ringed in central Norway. Eight of these originated in central Norway, four in Denmark, one in West Germany, three in France and two in Spain. Recoveries suggest that Greylag Geese migrate south during the autumn, and winter in central and southern Europe. Recoveries made in three counties of central Norway are comprised of one goose ringed in the Netherlands, two from southern Norway and 16 from northern Norway. These recoveries suggest that birds from northern Norway, rest in central Norway during the migration period.

After 1985, several recoveries from Denmark, the Netherlands, and Spain were reported for the period from September to April, and involved geese which were neck-ringed in Frøya and Leka municipalities in 1986.

Winter

Occasionally insignificant numbers of Greylags winter in central Norway.

EIDER Somateria mollissima

Breeding

Eiders breed along the entire Norwegian coast, and the total population is estimated at between 70,000 and 100,000 pairs (RØv 1984). Meanwhile, more recent data suggest that the breeding population may be significantly larger.

Eider eggs and down have been exploited at nesting localities in a multitude of coastal villages in Norway. Today, this practice is no longer common. Until 1970, the breeding population experienced obvious declines, but increases have been reported more recently (RØv 1984).

Coastal areas of TrØndelag and Helgeland are the most important breeding grounds in Norway. The numbers of breeding Eiders in these areas are presented on a map, but the accuracy of this material should be regarded with some reservation.

RØv (1984) provides the following figures for the breeding populations found in four counties within the influence area:

MØre og Romsdal		5,000 pairs
SØr-TrØndelag		4,500 pairs
Nord-TrØndelag		7-8,000 pairs*
Nordland (the entire county)		20,000 pairs
Total	ca.	37,000 pairs

* RØv (1984) mentions 13,000 pairs, but 5-6,000 pairs breed at Trondheimsfjord (Lorentsen & Bangjord 1979, Lorentsen & Rofstad 1982).

Statistics for Nord-TrØndelag are largely based on accounts of males recorded in the breeding area early on in the season, and represent accurate estimates of the total breeding population. These figures correspond well with those indicated on the map.

In SØr-TrØndelag and Nordland, statistics mostly included counts of females with young in June and July. This information was collected in association with a more generalized mapping of breeding seabirds. Experiences with these methods indicate that the resulting figures on breeding population size are far too low.

Previous population estimates of breeding Eider in the municipality of FrØya indicated a minimum of 2,000 pairs (Frengen & RØv 1975, Lorentsen & Bangjord 1984). These estimates, which were made as early as 1974, mostly involved broods of young birds late in the breeding season. Results from 1985, based on counts of males earlier in the breeding season, suggest that population size is actually significantly higher than assumed earlier. Although these results are also somewhat uncertain because the entire area was not investigated, the breeding population appears to be in the order or 4-5.000 pairs.

Proper mapping of breeding Eider should be carried out in SØr-TrØndelag and other areas of Norway. The 4-5,000 pairs of Eiders at FrØya alone are equivalent to the estimated 4,5000 pairs in all of SØr-TrØndelag county. There is considerable evidence suggesting that estimates of 70-100,000 pairs of Eider in all of Norway (Røv 1984) are extremely modest.

Without adequate data on breeding populations, it is difficult to evaluate the size of moulting and wintering populations. Updated estimates on coastal Eider should be attempted, and this may best be accomplished through aerial surveys at the end of April or the beginning of May. Eider live on the sea throughout the year, and are among those seabird species which are most vulnerable to oil contamination.

Moulting

Froan Nature Reserve is without doubt the most important moulting area for Eider in Norway. A total of 36.000 Eiders, mostly adult males, was recorded in Frøya municipality in 1985. This number is considerably higher than the number potentially recruited from the local breeding population, and the extent of Norwegian and/or birds originating from other countries is unknown.

Flocks of moulting Eider at Froan are shown on a map indicating shallows in the area (Fig. 5.6.4-7 and Tab. 5.6.7). These maps indicate that population distribution varied from 1985 to 1986. About 25,000 Eiders had congregated within a restricted area in the most exposed part of the archipelago in 1986.

At the present time, we have no adequate general picture of the population structure of Eider in Norway, a factor which makes it difficult to evaluate whether the entire moulting population along the coast is recruited from local breeding populations, or if they also include breeding populations from more northerly or easterly areas.

Eider are extremely vulnerable to oil contamination during moulting. To evaluate what may happen if an oil spill struck for example the Froan area during the moulting season, the following investigation should be given priority:

a) mapping of Eider during the breeding season

b) monitoring and ringing of moulting Eider

c) measures which may be employed to lead or frighten Eider away from the most dangerous areas in the event of an oil spill

Migration

Eider recoveries have been made in central Norway. 26 of these were originally ringed in the same area, while 13 others were ringed in Nord-Trøndelag (Trondheimsfjord). Recovery material only indicates local migrations, suggesting that the Eider populations in these areas remain in the same district throughout the year.

None of the recoveries indicate the origin of moulting Eider at, among other places, Froan.

Tab. 5.6.7 Moulting Eiders at FrØya in 1985 and 1986, see fig. 5.6.3 indicates areas which were not investigated during this period.

Area	1985		1986		
	Beg. of July	Mid. August	Beg. of July	End July	Mid. August
1	1.335	6.035	13.300	14.940	14.670
2	3.050	6.200	7.700	8.865	9.300
3	490	145	325	380	?
4	2.570	3.285	2.000	1.265	1.640
5	850	2.900	2.035	875	945
6	845	5.135	1.500	1.655	500
7	185	970	?	?	?
8	1.185	635	475	?	311
9	3.000	4.350	1.050	?	550
10	445	3.850	135	?	100
11	90	275	?	?	?
12	25	80*)	?	?	?
13	?	1.270	?	?	?
Total	14.070	35.130	28.520	27.980	28.520

*) End of July

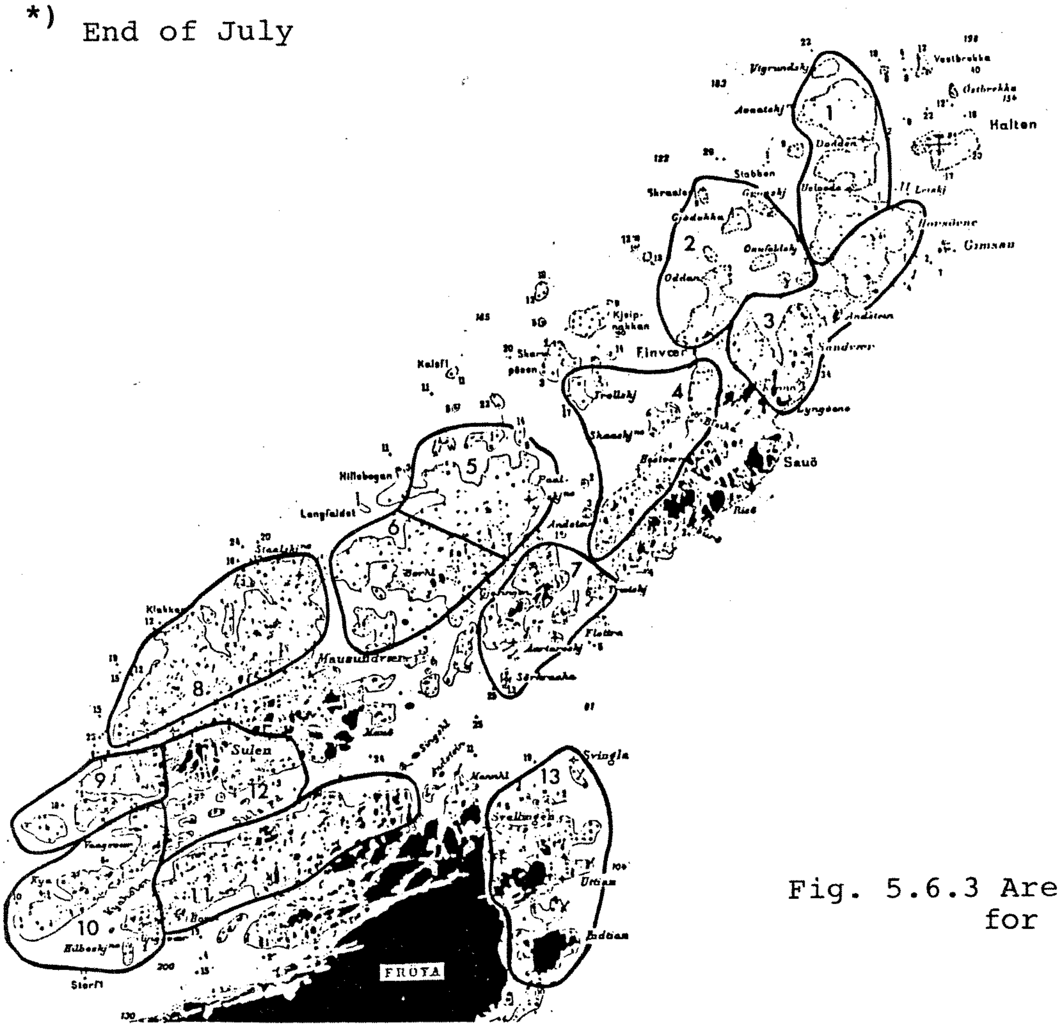


Fig. 5.6.3 Area subdivisions for Table 5.6.7.

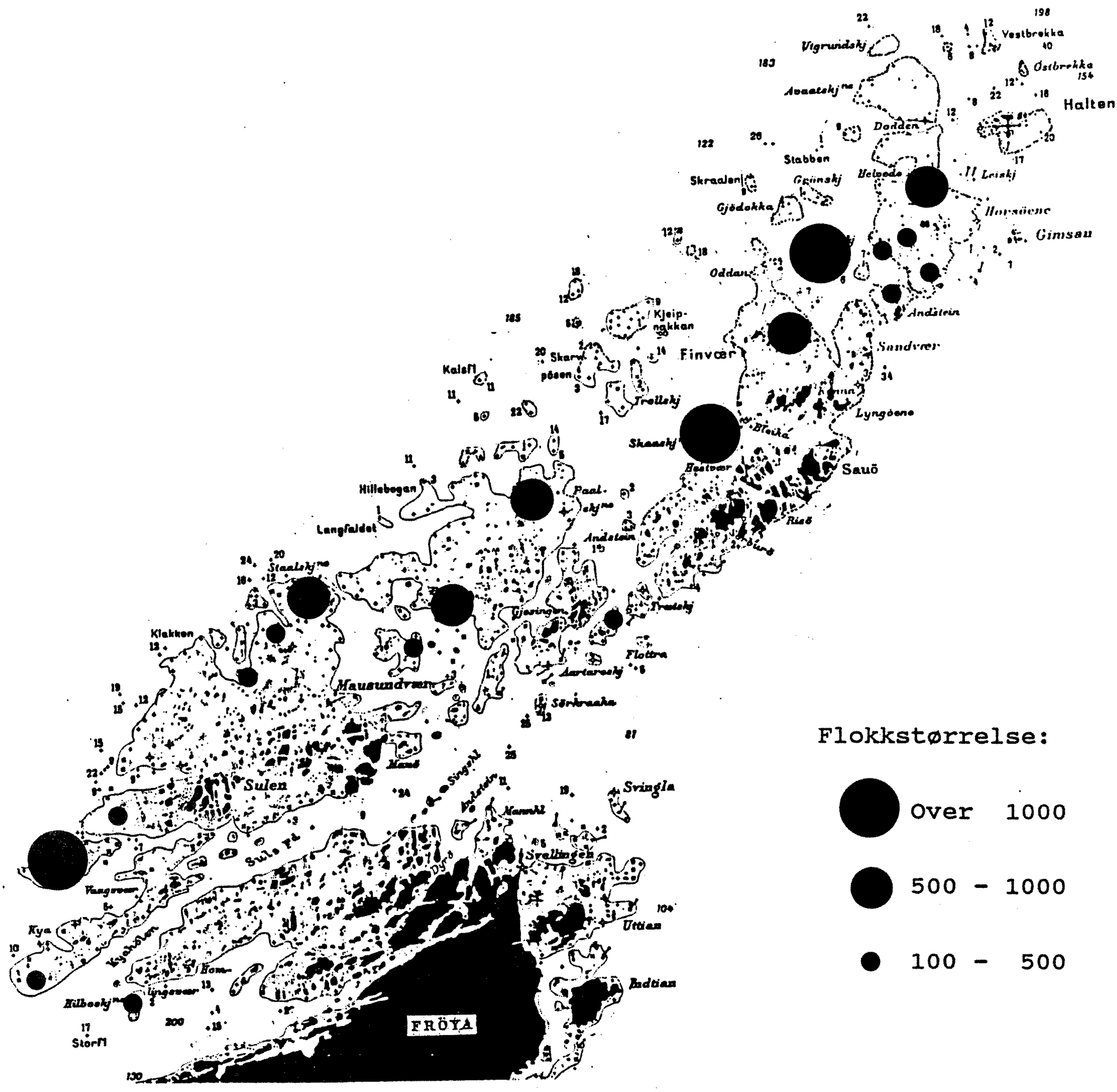


Fig. 5.6.4 Flocks of moulting Eiders at Frøya in the beginning of July 1985.

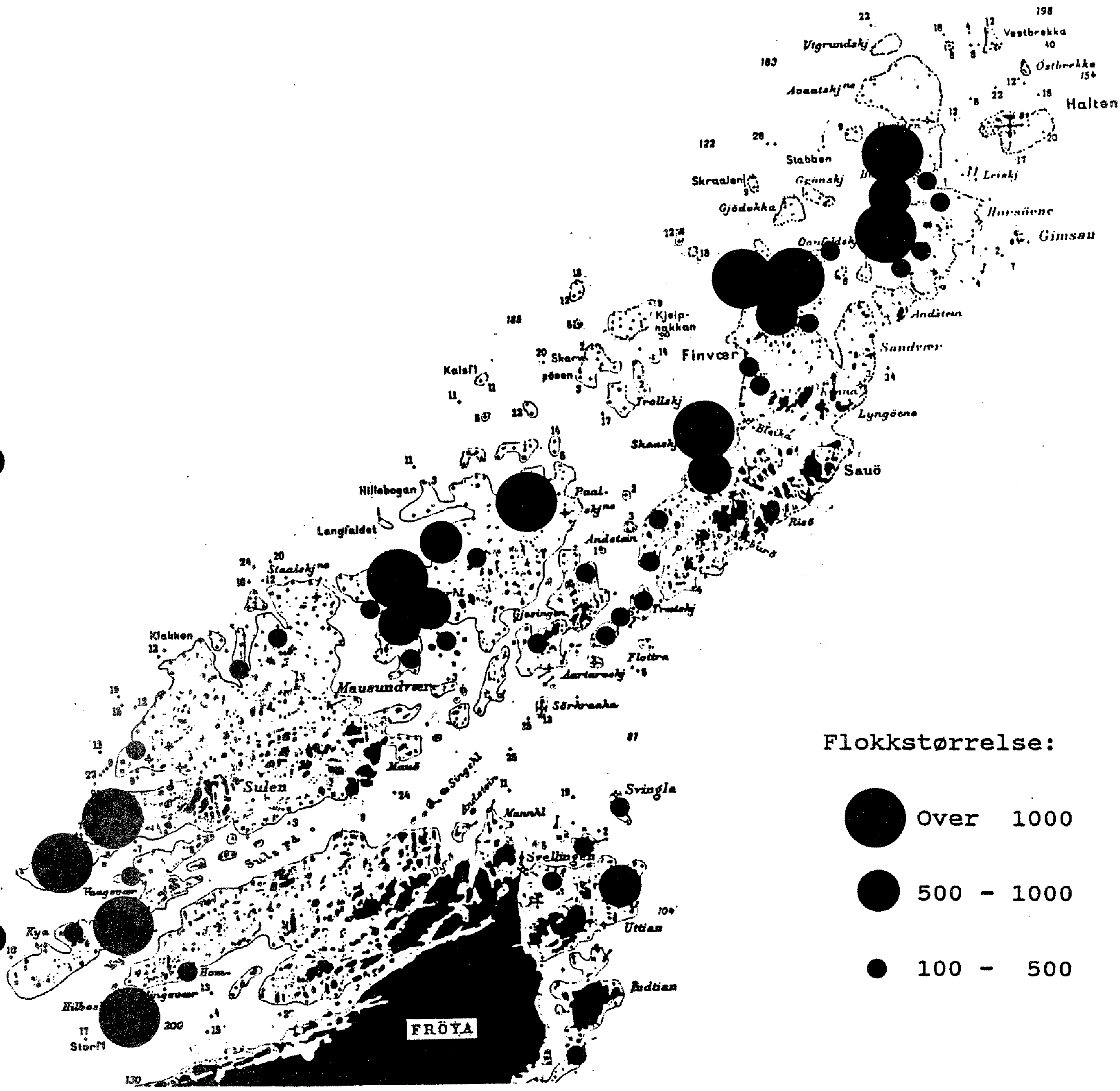


Fig. 5.6.5 Flock of moulting Eiders at Frøya in the middle of August 1985.

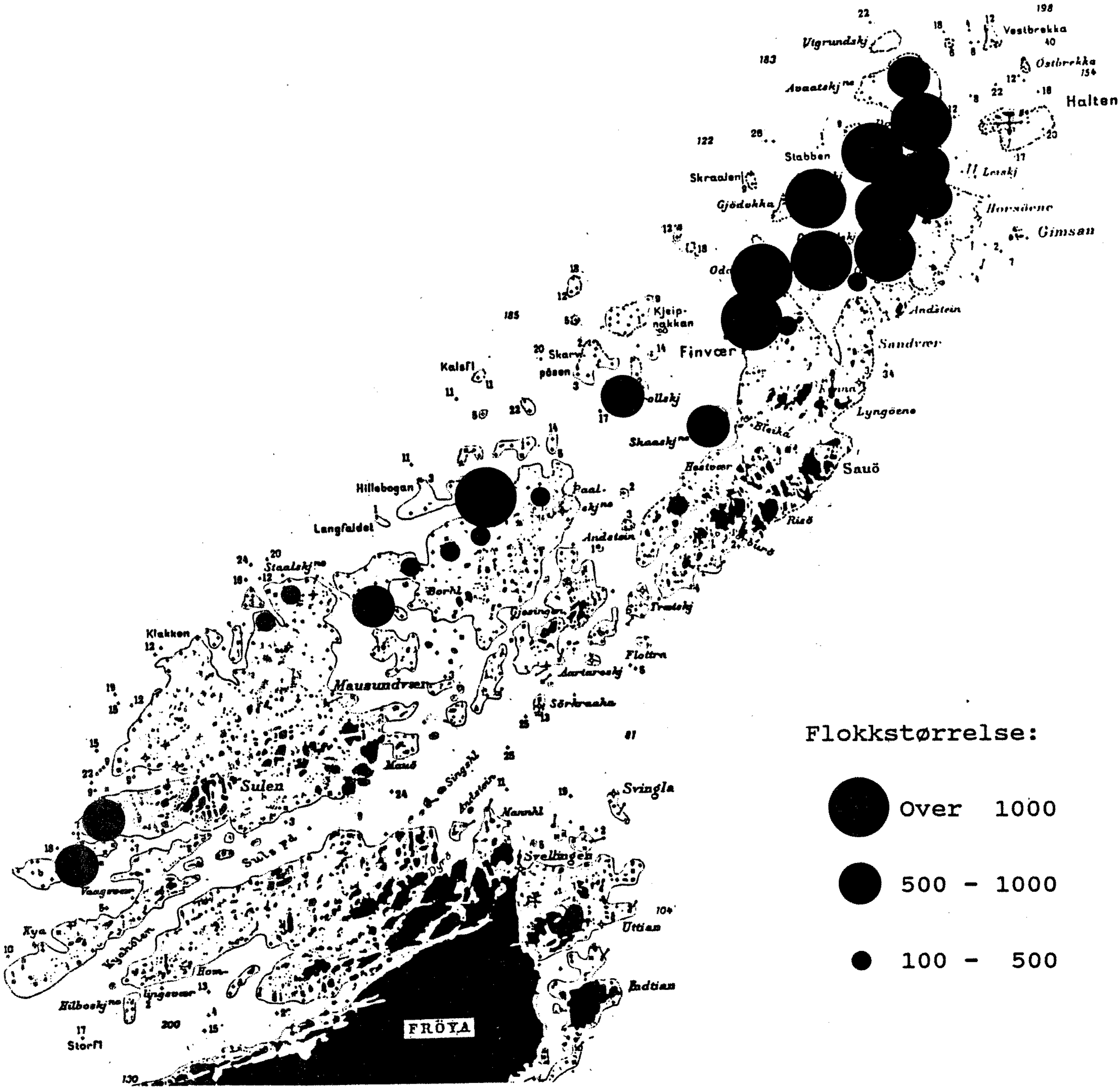


Fig. 5.6.6 Flocks of moulting Eiders at Frøya in the beginning of July 1986.

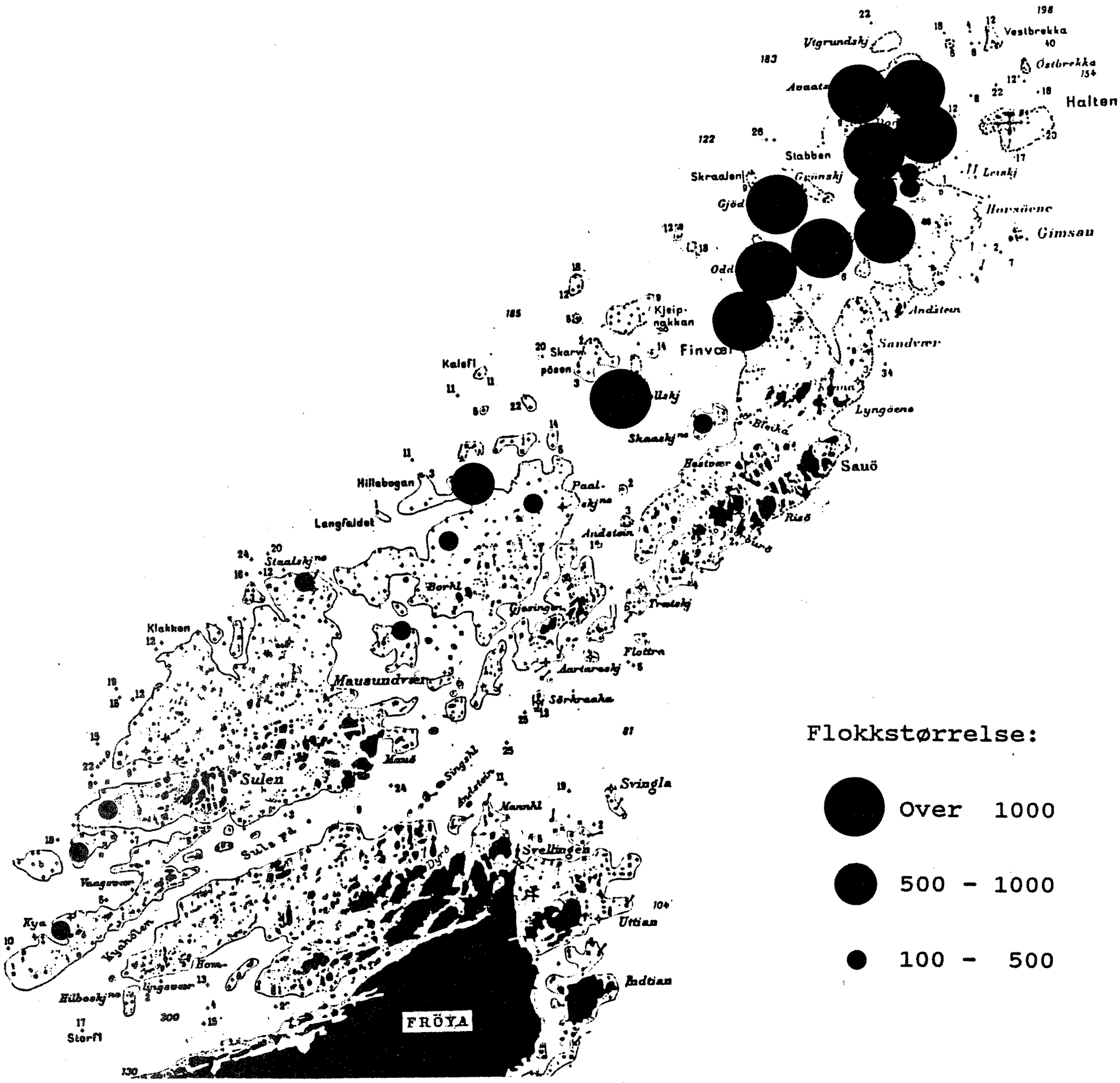


Fig. 5.6.7 Flocks of moulting Eiders in the middle of August 1986.

Winter

The Eider is assosiated with sea throughout its life cycle, and is the most abundant coastal seabird species in Norway during the winter. Counts within the survey area revealed numbers of about 140.000 individuals. The Eider is evenly distributed along the coast, and is especially numerous on the island of Vega (winter population about 25.000), and at Froan, Ørlandet and outer Vikna.

A large winter population has been documented in the survey area. Their distribution contrast with that of the moulting period, emphasizing the inadequacy of our current knowledge about Eider populations found along the coast at different times of the year. Further research is required in order to carry out comprehensive consequence analyses.

Population Variations

Annual mid-winter counts of the same areas along the coast indicate a recent decline in the eider duck population (Fig. 5.6.8). The reasons for this decline are unknown. The large, year round population of eider ducks is in many ways characteristic for species in the area under discussion. Increased drilling activity will necessitate accurate monitoring of the further developments within this population.

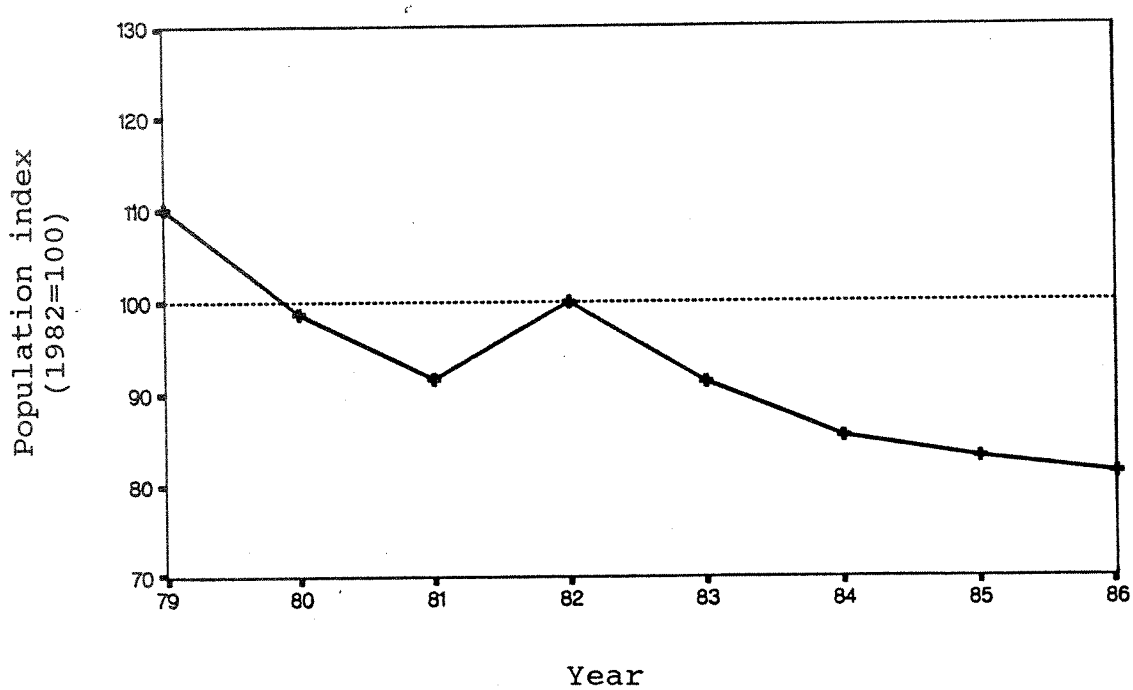


Fig. 5.6.8 Population developments among Eiders in Norway from 1979 to 1986, based on annual winter counts at fixed areas (Seabird Project unpubl.).

KING EIDER *Somateria spectabilis*

The King Eider is a high arctic species which does not breed in Norway. This species winters in northern Norway, and may regularly winter as far south as Sør-Trøndelag county. The survey area lies on the outer limits of the normal winter distribution of this species, although they may occur to a varying degree from year to year.

Røst and Værøy are important winter sites. The winter population is estimated to about 6.000 individuals in 1987.

COMMON SCOTER *Melanitta nigra*

This is an abundant seaduck, but there are no important winter sites for this species along the Norwegian coast.

Bispøyan in Hitra seems to be a regular winter site in Sør-Trøndelag, but it is not known to what breeding populations these birds belongs, and thus it is impossible to evaluate the consequences of an oilspill in this area on this species.

VELVET SCOTER *Melanitta fusca*

Breeding

The breeding range extends from Norway and eastwards in the Palearctic, and the species is an inland breeder in our country. Breeding numbers in the western Palearctic are everywhere quite low. It is one of the least abundant of the sea ducks, and is considered extremely vulnerable to the effects of oil pollution.

Moulting

The moulting population of Velvet Scoter in the survey area is outstanding in Europe, and is comprised of a minimum of 11.000 individuals.

Ørlandet, with 7.000 individuals recorded in 1985 and a minimum of 5.000 in 1986, is the most significant area for Velvet Scoter in Norway. Their numbers in this area appear to have increased considerably (Follestad et al. 1986).

Vega is the most important moulting area for Velvet Scoter in Nordland county, although the population there seems to have declined.

A large concentration of about 500 individuals has been recorded on Smøla.

Winter

The Velvet Scoter is a marine species outside the breeding season, during which it exhibits flocking behaviour and has a very localised distribution. The most important wintering areas are Ørlandet, Smøla, inner parts of Frøya, Tarva in Bjugn, Outer Vikna and Vega.

A significant increase in numbers of wintering Velvet Scoters in Sør-Trøndelag county was demonstrated from 1977 to 1985/86 (Follestad et al. 1986). The reasons for this increase are unknown, but must be regarded in the context of an increase in the moulting population. This species should be monitored over a larger area if the extent of the wintering area has altered during recent years.

RED-BREASTED MERGANSER *Mergus serrator*

Breeding

Red-breasted Merganser mostly breed in freshwater habitats, but are also commonly found along the coast. We have little information on breeding populations found in the area discussed in this report, because most seabird investigations are conducted in June and July. Breeding Red-breasted Mergansers should be counted early in May, while males are still in the breeding area.

Recent data from the beginning of May in 1987 indicates a breeding population of at least 150 pairs in the vicinity of Smøla (exclusive of individuals breeding on Smøla), and a minimum of 20-25 pairs at Linesøya, Åfjord.

Red-breasted Mergansers are considered extremely vulnerable to oil contamination.

Moulting

Mapping of moulting Red-breasted Mergansers was only given priority in Frøya. The total number represented is therefore an absolute minimum. Their documented numbers are however among the highest in Europe, with a moulting popultion of approximately 10.000 individuals. Birds congregating within this area, probably originate from a substantial part of their breeding range in Fennoscandia.

Frøya is the most important moulting area.

Smøla is an other important area, and the population there has approached 650 individuals. Dispersed flocks have also been observed on the Romsdal coast.

Recent data from Sør-Helgeland emphasizes the importance of this region for moulting Red-breasted Mergansers. The data base for this species is even less adequated than for Greylag Geese, because most surveys are conducted prior to the beginning of their moulting season.

Existing data indicates considerable variation between the results from 1974-1980 and those from 1985, suggesting a significant population decline.

Winter

The winter population constitutes a sizable part of the European population. The origins of those populations occuring along the Norwegian coast are unknown (cfr. Follestad et al. 1986).

SEA EAGLE *Haliaeëtus albicilla*

Although the Sea Eagle is not considered a true seabird, in Norway this species is entirely dependent on the sea for food. Fish and seabirds make up most of its diet. Through consumption of soiled seabird carcasses, Sea Eagles may be exposed to internal damage and even poisoning.

Breeding

The vast majority of all European Sea Eagles nests in Norway, and the population has approached 1,000 pairs. A very large percentage of these breed within the influence area of the Heidrun field.

Sea Eagles nest at several locations on small islands and islets in the outermost archipelago, and disturbance, like that associated with clean up efforts after an oil spill, should be avoided in the vicinity of Sea Eagle nests.

Winter

The influence area of Heidrun is the main wintering area of Sea Eagles in Norway. The winter population is probably composed mainly of Norwegian birds.

WADERS *Charadriidae*

Waders include several species, all of which are considered less vulnerable to oil contamination. Conflicts with oil slicks may take place in situations where oil washes ashore in zones where waders search for food. Wetlands are important wader habitats, for example the wetland system at Ørlandet.

KITTIWAKE Rissa tridactyla

Breeding

Kittiwakes breed in outlaying areas along the entire coast, and the largest colony in Norway, with an estimated 60,000 pairs, is located at Runde. Farther north, large colonies are found on the islands Røst and Vedøy, comprising 23,000 and 19,000 pairs respectively (refer to Figure 5.6.1).

Several smaller colonies are located within the area under discussion, and many have experienced serious population declines or reproductive failure in recent years.

Kittiwakes are not considered particularly vulnerable to oil contamination. However, because the population has radically declined after 1970, and the present population at Runde is only about 40% of what it was fifteen years ago (Fig. 5.6.9), they are mentioned in this report. The colony at Halten has also experienced a serious reduction in numbers of nests from 1,666 in 1974 to only 105 in 1986 (Lorentsen 1986). In the given situation, additional damage related to oil contamination may reinforce an increasingly negative trend.

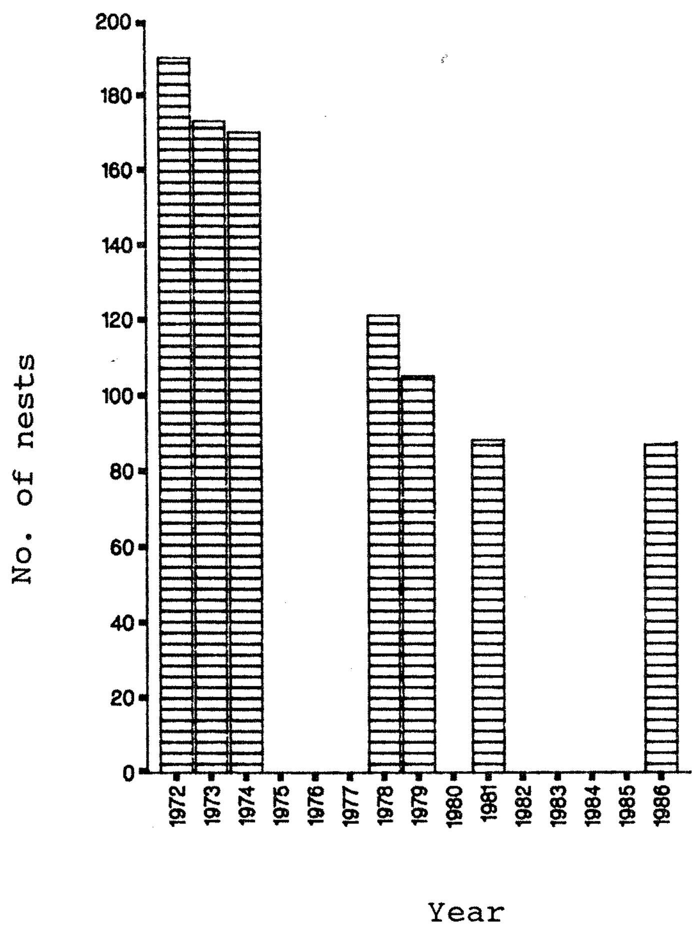


Fig. 5.6.9 Population developments among Kittiwakes at Runde between 1972 and 1986, based on study areas.

GUILLEMOT <u>Uria aalge</u>

Breeding

Runde is the only large Guillemot colony in southern Norway, and represents a population of about 10,000 pairs (Fylkesmannen i Møre og Romsdal 1985).

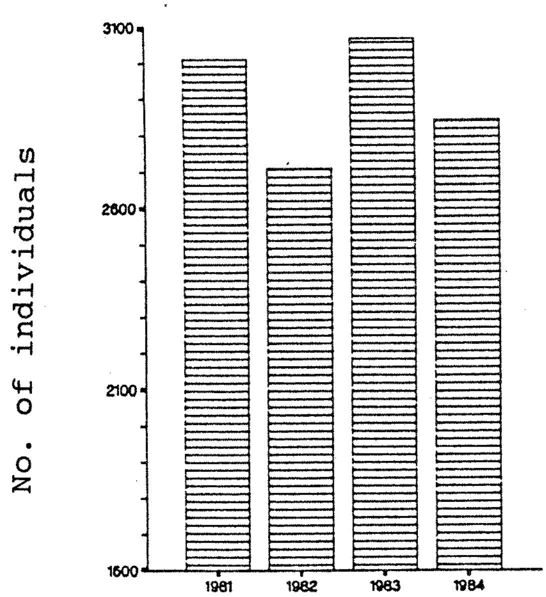
Heavy population declines in northern Norway during recent years have resulted in that the colony at Runde may be the largest in the entire country which still supports a stabilized population (Fig. 5.6.10). Meanwhile, because studies were conducted during years which were favourable for several species at Runde (Røv 1984), we are hesitant to regard these results without some reservation.

Larger colonies farther north, are first found on Røst and Værøy which support populations of 4,000 and 2,000 pairs respectively (see Fig. 5.6.1).

Elsewhere in the influence area, the species is only found in limited numbers. At Sklinna the population is roughly estimated at between 30 and 40 pairs.

Guillemots assemble in breeding colonies long before the start of egg-laying, and on certain days (often at 3 to 4 day intervals) large flocks of Guillemots and other auk species may congregate just outside the colony. Most of these individuals are sexually mature birds and represent the most vulnerable segment of the population. Their whereabouts during interim periods, or whether they congregate within the influence area of the Heidrun field en route to the colony, are factors about which little is known.

Young birds jump into the sea when they are three weeks old, before they are able to fly. They begin a swimming migration (post breeding movements) mainly in a northerly direction toward Haltenbanken (see separate section about these movements).



Year

Fig. 5.6.10 Population developments for Guillemots at Runde between 1981 and 1985, based on study areas (see Røv 1984).

Migration based on (ring recoveries)

A total of 152 recoveries of Guillemots ringed at Runde were reported as of 1985, and yield considerable information about migration patterns. Most finds are made along the Norwegian coast during the autumn and winter. Only eleven finds were made in foreign countries. Recoveries show that the Guillemot population at Runde spreads along the entire Norwegian coast from Troms to Rogaland during the autumn, and it appears that more birds migrate north than south (Fig.5.6.11). Several recoveries were also made along the coast of Sørlandet and Østlandet, later in the winter. All eleven finds made in foreign countries were reported from coastal areas along the North Sea.

Several birds ringed in other areas, including northern Norway and Murmansk have also been recovered. However, most of these stem from breeding areas to the west including the Faroe Islands, Shetland and the rest of Great Britain, and some from Helgoland.

Recoveries clearly demonstrate that the coast and nearer open sea areas off central Norway and Helgeland are used by part of the wintering population from Runde. Although little is known about the composition of the wintering population, the area is also used by birds from some Guillemot populations from northern Norway, northern Russia, Great Britain and the Faroe Islands.

The migration pattern of Guillemots is partially illuminated by recoveries of ringed Guillemots at several different location in Europe (Mead 1974, Baillie 1982). These recoveries demonstrate that ringed Guillemots from Helgoland, eastern England and the northern parts of Scotland occur in southern Norway. A large number of birds also originate from colonies in the Faroe Islands (Olsen 1982).

Post breeding movements from Runde

Preliminary investigations were carried out in 1985, and field work was divided into three phases:

a) date of departure and extent of jumps by young birds
b) dispersal of young and adult birds away from the colony
c) distribution and density at open sea

Phases (a) and (b) were carried out by Fylkesmannen i Møre og Romsdal (1985).

Departure dates: In 1985 most young Guillemots jumped into the sea during the first half of July. The majority jumped either just prior to, or shortly following sun-set.

Dispersal from the colony: Observations are somewhat lacking for 1985, because of poor reproduction and difficult weather conditions. However, observations do clearly indicate that birds migrated in a northwesterly direction during initial phases. After clearing land, some individuals turned in a more northerly or easterly direction. The number of adults and young observed at distances from Runde are too small to discover the relative frequencies of the different migration directions. The material indicates migrations out toward open sea as well as into the fjords.

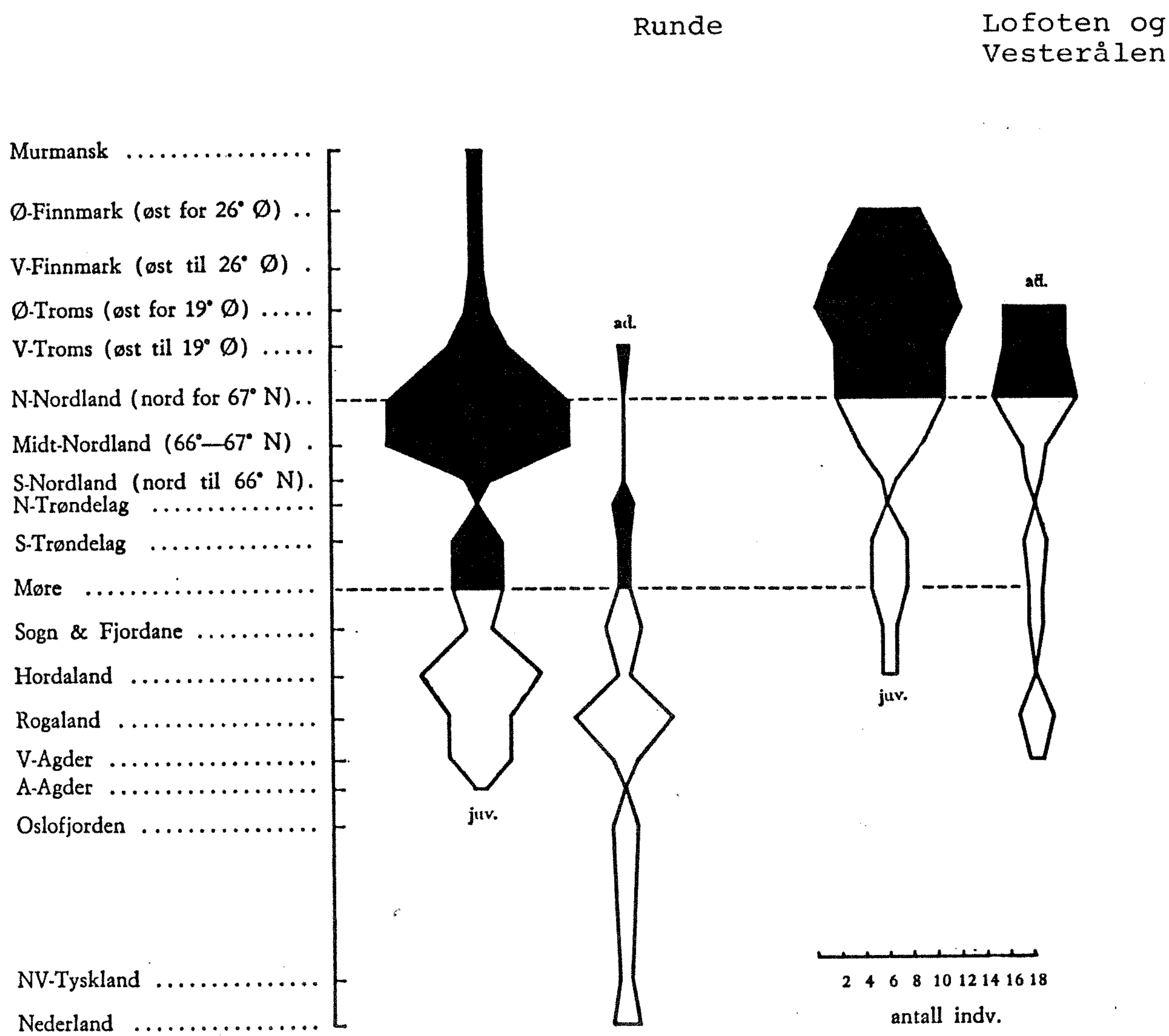


Fig. 5.6.11 Recoveries of Guillemots from September to April. All birds were ringed as young at Runde (two figures to the left) and in Lofoten and Vesterålen (two figures to the right). Black = north of the breeding area. White= south of the breeding area (from Haftorn 1971).

Distribution and density at open sea: No large open sea stretches were investigated, and one should exercise caution when interpreting results.

Differences between Razorbills and Guillemots were quite clear during these investigations. Far greater numbers of adult Razorbills and their young were observed in the fjords than Guillemots. These results comply with observations from previous years.

Figure 5.6.12 indicates the distribution of young Guillemots in the investigation area in July-August 1985.

As early as July 20th, significant densities of Guillemots and young were recorded at Haltenbanken (Fig. 5.6.13). The same tendency was observed in August, and the highest densities were found along the stretch between Kristiansund and Haltenbanken in the beginning of August (Fig. 5.6.14). Some less young were observed around August 20th (Fig. 5.6.15), but weather conditions were poorer than during previous excursions.

Haltenbanken appears to be an important area for Guillemots, where densities of between 2 and 5 birds were observed per km^2 in August. A greater tendency by Guillemots toward northerly migrations corresponds with ringing recovery results. In that hardly any birds at all were seen in the area between Haltenbanken and the mainland, the tendency by young Guillemots to remain at Haltenbanken is conspicious. Meanwhile, several Guillemots and young have been observed near land during the course of other field work. We are unable to ascertain whether both groups originate from the population at Runde, or in which case if their distribution is associated with Runde migration patterns where some individuals migrated toward open sea while others moved into the fjords.

The distribution of Guillemots without young in July-August 1985 is shown in Map appendix. The population from which these individuals originate has not been identified. The highest densities were also found at Haltenbanken.

Post Breeding Movements from Røst

Preliminary investigations were carried out in 1985 (Anker-Nilssen 1985) using the same format for investigations as at Runde, and only the following two aspects were studied:

a) date of departure and extent of jumps by young
b) dispersal of young and adult birds away from the colony

Research was conducted by the Røst Project at the Zoological Museum in Oslo.

Departure date: Most young Razorbill and Guillemot jumped into the sea at the end of July or beginning of August in 1985, somewhat later than normal. Production of young at Røst was poor in 1985.

Dispersal from the colony: Only 7 young Guillemot and 9 young Razorbills were observed, all on the same day in near coastal waters. Once birds had left the islands at Røst for deeper water, they were impossible to locate.

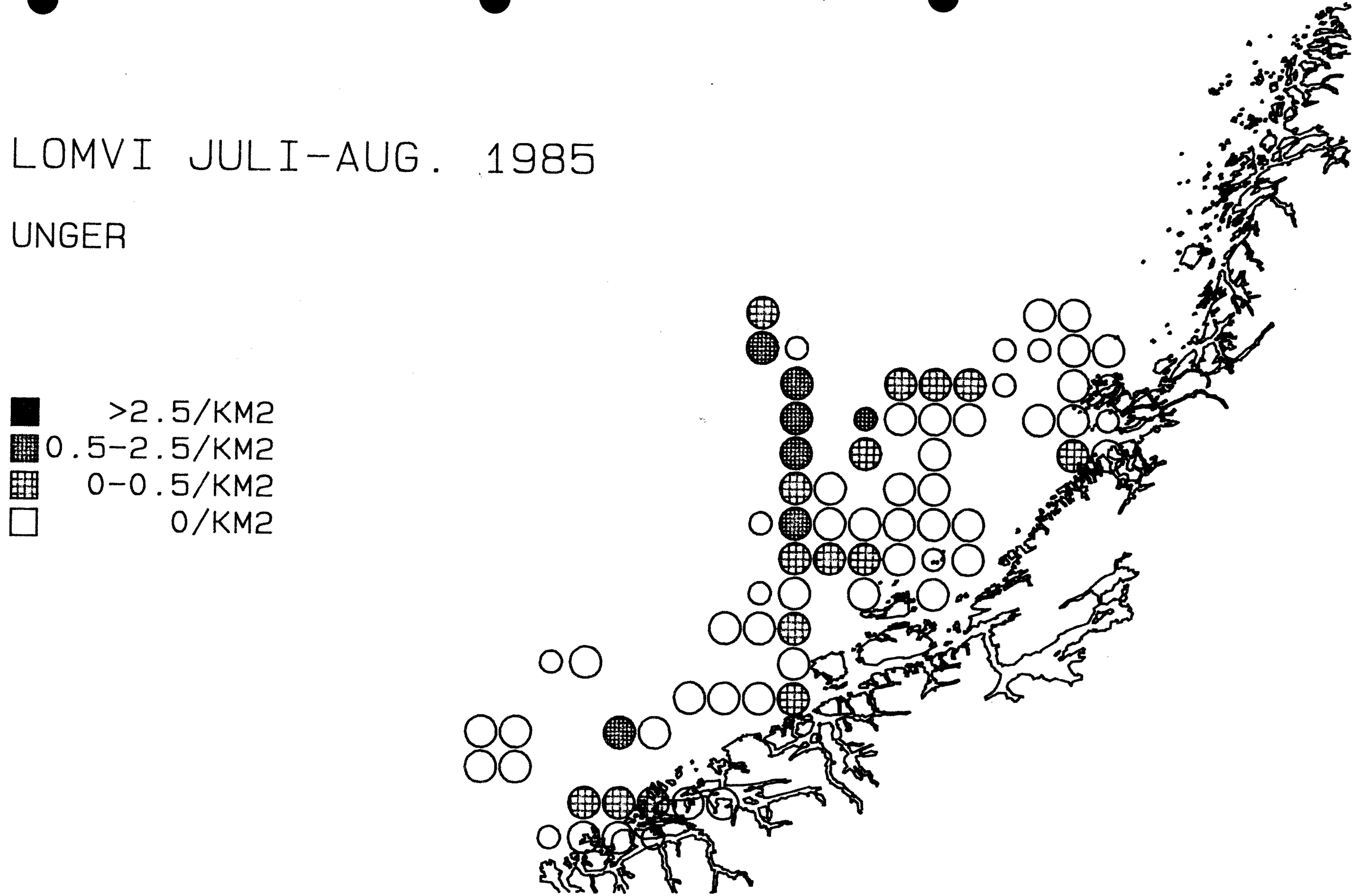
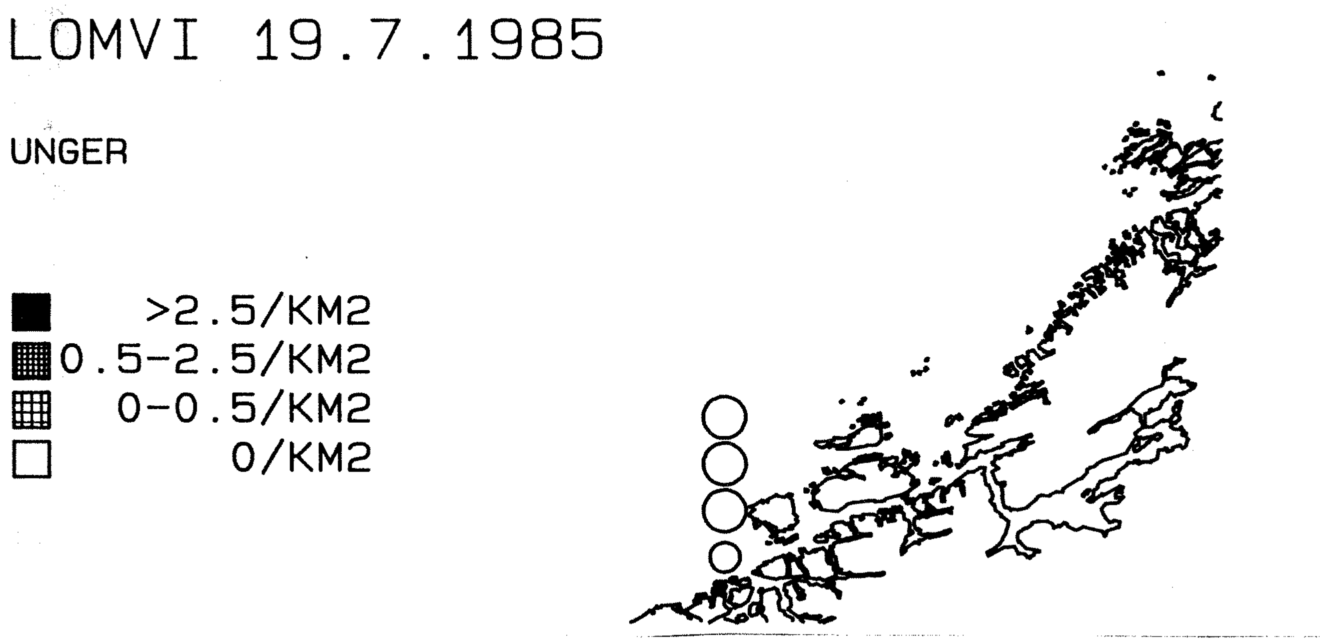
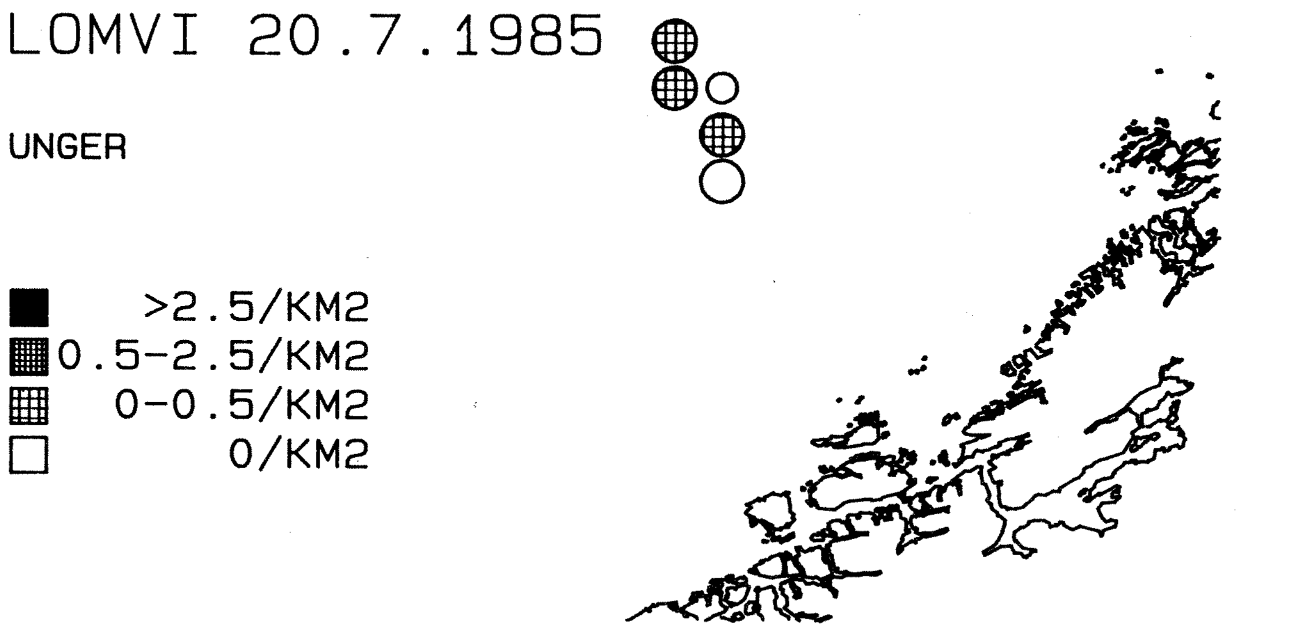


Fig. 5.6.12 Density of young Guillemots at sea July-Aug. 1985. Small symbols show a survey distance of less than 6 km.





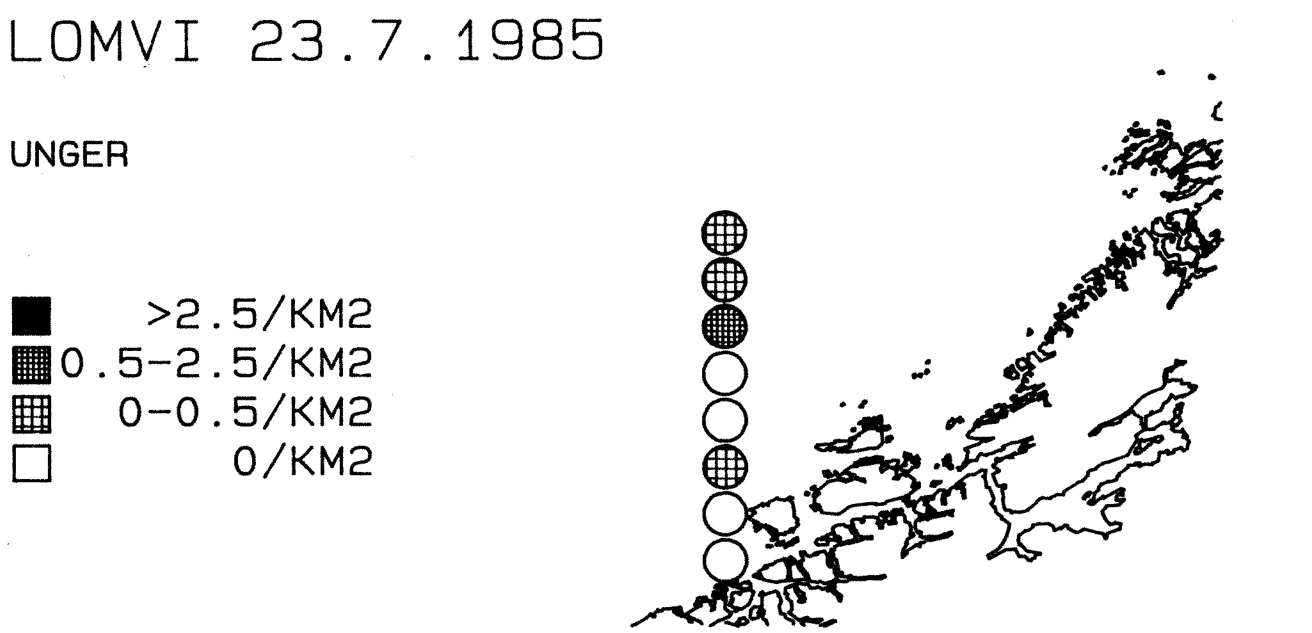


Fig. 5.6.13 Density of young Guillemots at sea in a transect from Kristiansund to Haltenbanken 19.-23.7. 1985. 20.7. the ship moved between the platforms at Haltenbanken.

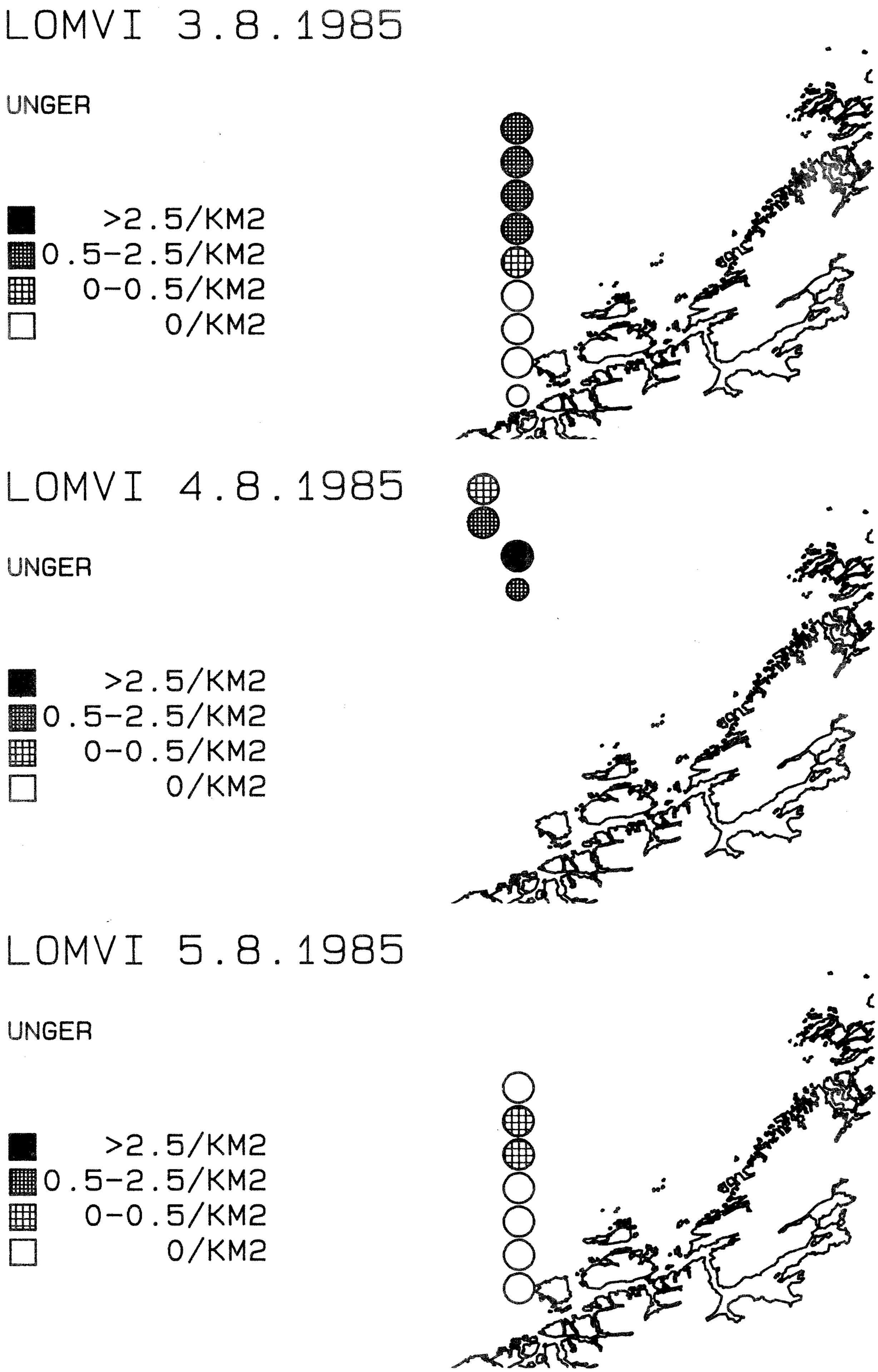


Fig. 5.6.14 Density of young Guillemots at sea in a transect from Kristiansund to Haltenbanken 3.-5.8. 1985. 4.7. The ship moved between the platforms at Haltenbanken.

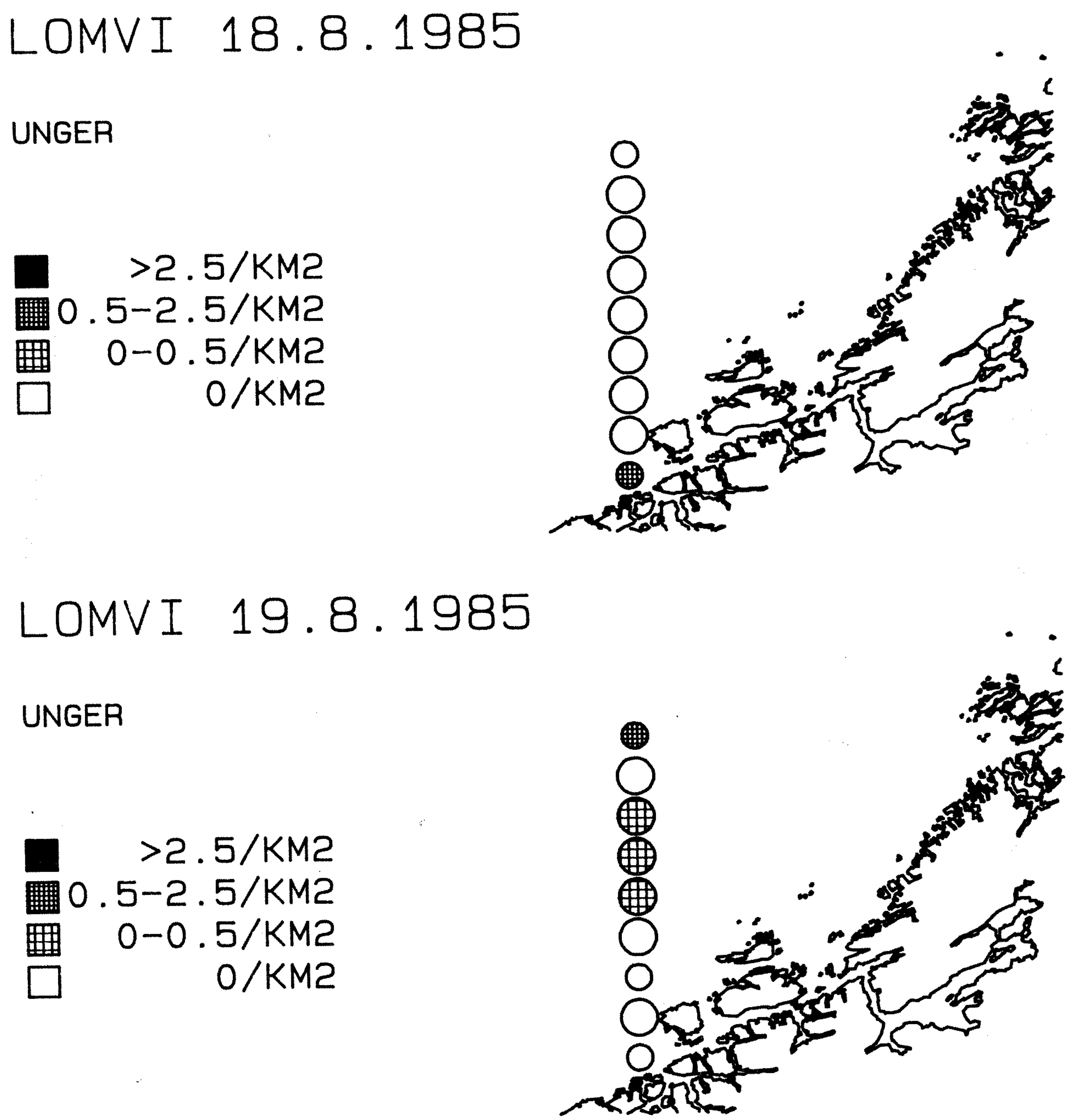


Fig. 5.6.15 Density of young Guillemots at sea in a transect from Kristiansund to Haltenbanken 18.-19.8. 1985. A strong wind 18.8. made it difficult to observe birds at sea.

Therefore we were unable to determine the sequence of events associated with, or the direction of, this swimming migration away from Røst.

Post breeding movements from colonies in the British Isles

On the basis of comprehensive mapping of seabirds at open sea in Britain, Blake et al. (1984) contends that there is no direct evidence to support suggestions by Mead (1974) that young birds incapable of flying accompanied by one of their parents, swim across the northern part of the North Sea from colonies in England and Scotland in one enormous migration to southwestern Norway.

The highest numbers of recoveries of Guillemots which are ringed in England or Scotland, are recorded in Norway in October and November. In the light of these recoveries, Blake et al. (1984) assume that Guillemots first leave Great Britain in September.

One of our seabird observers participated in an excursion in July 1986, (Fig. 5.6.16). Several Guillemots but rather few Razorbills with young were observed. The material has yet to be adapted for the Seabird Project Mapping Program, but preliminary totals of observations made during this excursion indicated the following numbers of young:

	Date (July)																	
Species	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Total
Guillemot	-	1	2	8	11	10	12	1	10	10	14	10	34	70	3	7	-	203
Razorbill	-	-	-	-	1	3	-	1	-	1	2	3	5	-	-	-	-	16

Figure 5.6.17 show the distribution of young Guillemots found in the northerly parts of the North Sea. Significant concentrations of adult Guillemots with young are found in several areas, indicating that large migrations of auks with young across the North Sea occur shortly after they leave their colonies.

We emphasise that these assumptions are only based on results from one excursion, and caution should be exercised in drawing detailed conclusions. However there are reasons for suggesting an early migration, particularly of Guillemots and young, across the North Sea. The extent of this migration, the populations represented, and the general direction are unknown.

It is uncertain as to whether some birds continue into the Skagerrak area, or move in a more northerly direction to coastal areas of both Trøndelag counties and Helgeland. A considerable number of British Guillemots are found in these areas, and one may not rule out the possibility that some of the birds registered at Haltenbanken in Augugst, may originate from British populations (see migration section).

Further mapping is needed to evaluate the degree to which an oil slick from Heidrun may affect the swimming movements of auks from Great Britain and the Faroe Islands. In July and August, adult birds have moulted their primary feathers and are incapable of flying. They are therefore extremely vulnerable to oil contamination during this period.

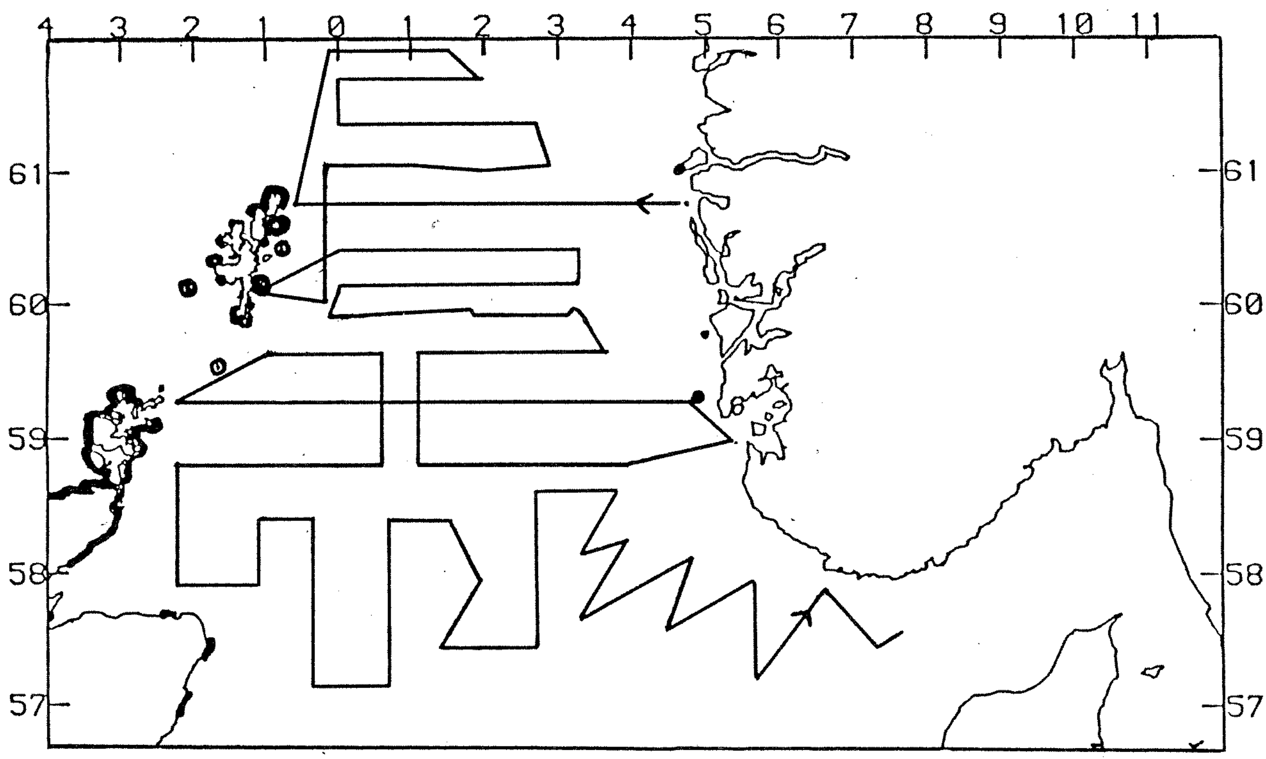


Fig. 5.6.16 Excursion route during observations of the swimming movements of Guillemots and Razorbills in the North Sea, July 11-27, 1985 (see figures 7.9 and 7.10).

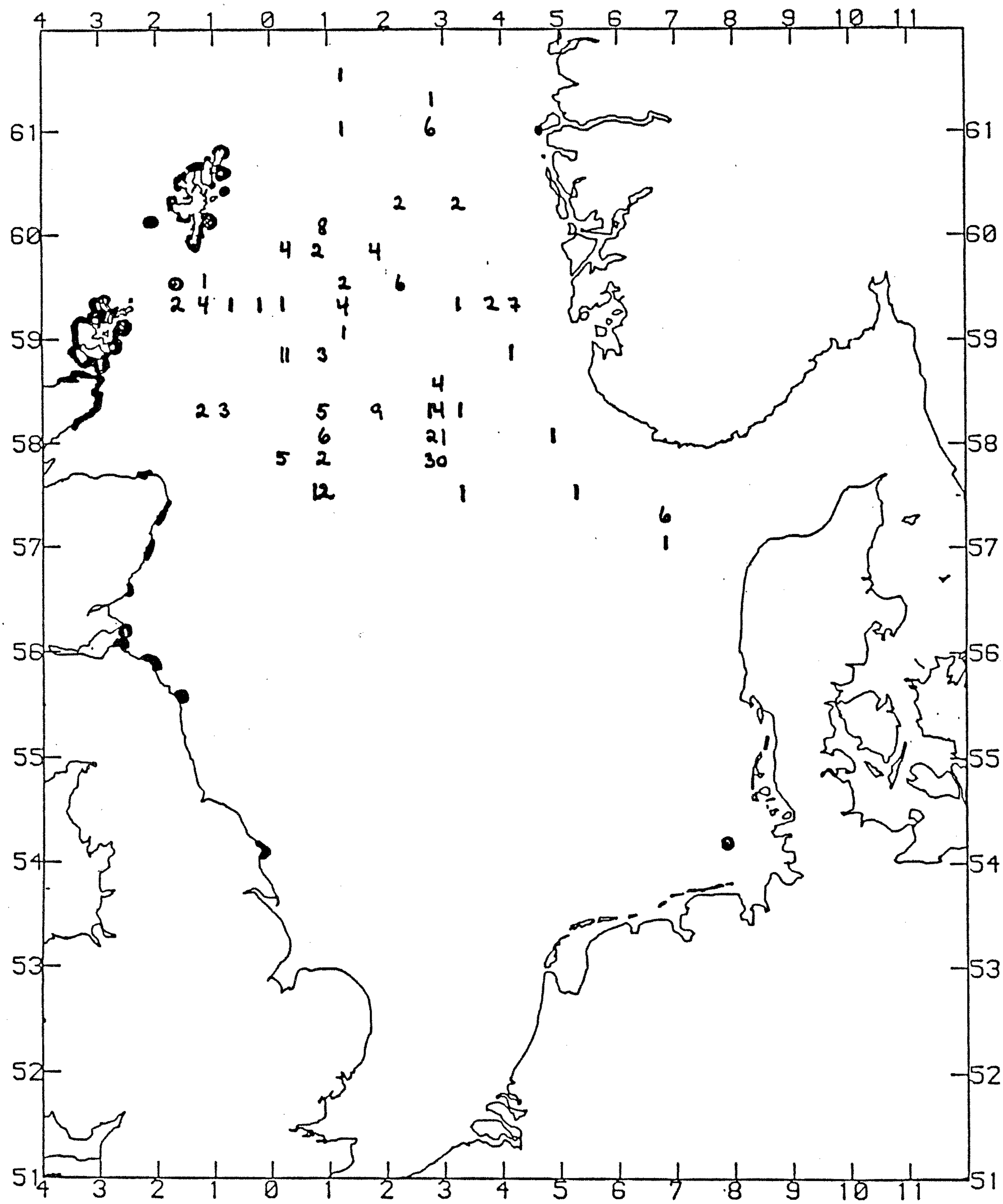


Fig. 5.6.17 Approximate distribution of 203 young Guillemots observed in the northerly part of the North Sea 11-27.7.1986. The map also shows breeding colonies of Guillemots (after Blake et al. 1984).

RAZORBILL *Alca torda*

Breeding

The only substantial colony of Razorbills in southern Norway is at Runde, where the population is about 3.200 pairs (Fylkesmannen i Møre og Romsdal 1985). There are some small colonies on the coast of Sogn og Fjordane.

Larger colonies farther north are first found on Røst and Værøy, which support populations of 4,000 and 800 pairs respectively (see Fig. 5.6.1).

Razorbills also congregate at colonies prior to egglaying (see section about Guillemots).

Migration (based on ring recoveries)

Only 14 recoveries have been made of young Razorbills ringed at Runde. Two of these recoveries are from central Norway (June and September), one from southern Norway, three in Denmark, and seven further south (Ireland, East Germany, the Netherlands and France). Although recoveries are few, they do indicate that the breeding population at Runde migrates south during the winter.

On the other hand, in that 6 recoveries of Razorbills ringed in northern Norway have been made in the influence area between October and March, the area appears to be important for wintering birds from northern Norway. We have no information about the number of birds which may winter in the influence area.

Several Razorbills ringed in Great Britain have also been recovered in the influence area, as well as some birds from Sweden and the Soviet Union.

Postbreeding movements from Runde and Røst

Preliminary inverstigations were carried out in 1985, se section about Guillemots. Data on departure dates and dispresal from the colony are very scarce at Runde.

Razorbills tended to migrate into the fjords in 1985, in association with higher access to nutrient resources. No Razorbills with young were observed in open sea areas north of Runde.

Ringing recoveries demonstrate that some young Razorbills migrates in a southerly direction during the autumn, but we have no information on whether this movement takes place before or after the end of the adult moulting period.

During a southerly migration from Runde, Razorbills and their young are unlikely to be exposed to oil contamination from Heidrun field along the coast and at open sea. However, it is emphasized that background data is not sufficient for evaluating the extent or speed of southerly migrations.

Although no Razorbills accompanied by young were observed, some individual Razorbills were seen in the investigation area. The populations from which these individuals originate have not been identified.

Figure 5.6.18 show the distribution of young Razorbills found in the northerly pars of the North sea in July 1986.

Very few young Razorbills were observed at sea compared with the numbers of young Guillemots, and a possible explanation to this is that the postbreeding migration of Razorbills takes place somewhat later in the autumn.

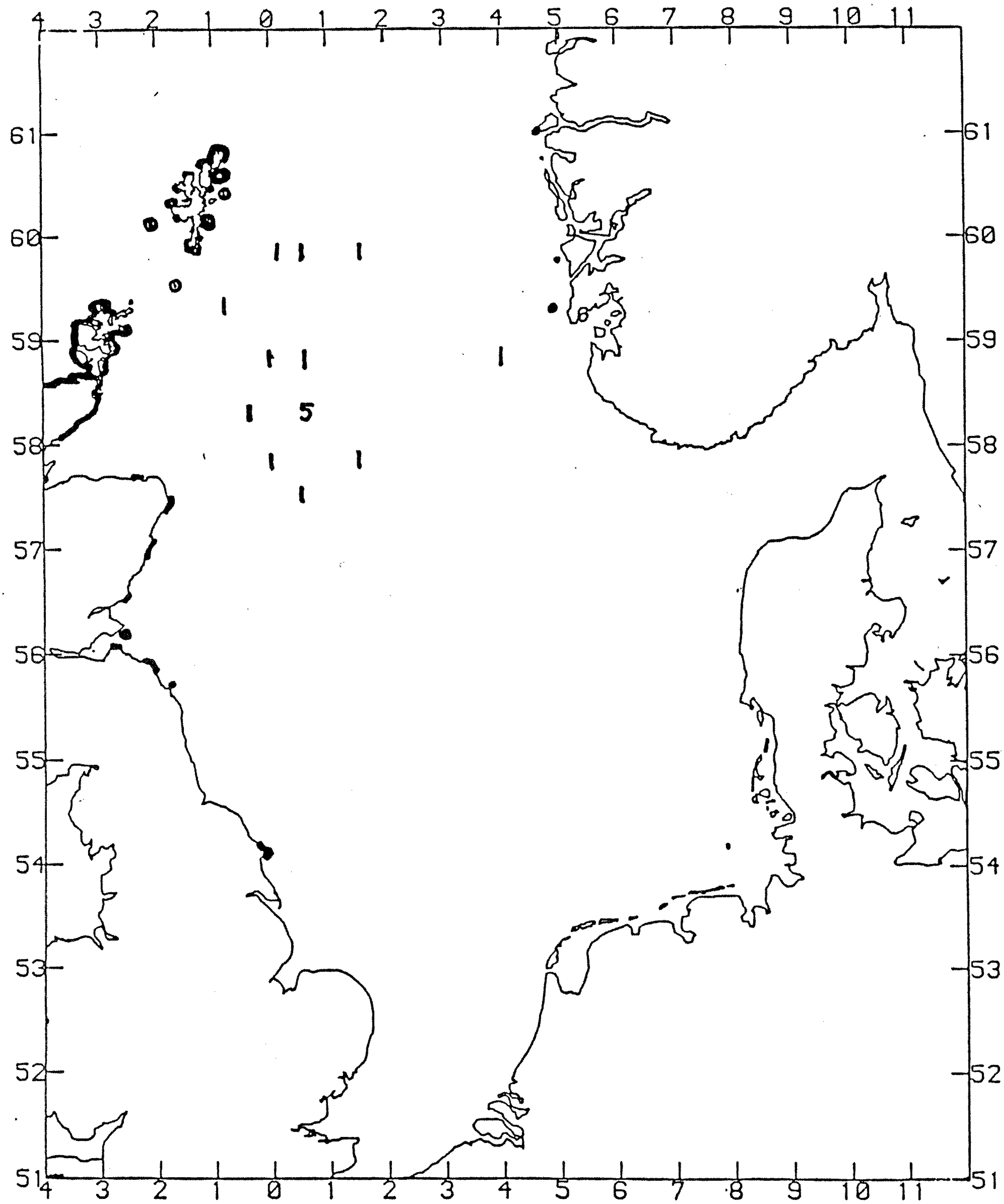


Fig. 5.6.18 Approximate distribution of 16 young Razorbills observed in the northerly part of the North Sea, 11-27.7.1986. The map also indicates breeding colonies (after Blake et al. 1984).

BLACK GUILLEMOT *Cepphus grylle*

Breeding

The Black Guillemot breeds in individual pairs, or in small loose colonies in outlying coastal areas. The largest colonies are found in the most isolated islands and skerries, a factor related to the abundance of mink which are a serious predator (Folkestad 1982).

Few reliable figures (probably none) are available for breeding populations of Black Guillemots in Norway, and considerable methodological problems are encountered in evaluating the abundance of this species (see Munkejord 1983).

The entire population is estimated at between 11,000 and 19,000 pairs (Evans 1984). The distribution and occurrence of Black Guillemots in the area discussed in this report is based on results of counts which yielded a total of 14,000 individuals. This figure is partially based on estimates of the breeding population, and to a much greater extent on counts of individuals found in colonies. It is therefore difficult to evaluate the size of the breeding population (see Munkejord 1983). At best, these results may be representative for other areas along the coast.

Froan supports by far the largest numbers of Black Guillemot in both Trøndelag counties, with an estimated population of about 2,000 pairs (Frengen & Røv 1975). The Black Guillemot is also found in greater numbers on the coast of Helgeland, especially on some localities in Vega.

Migration

Most Black Guillemot recoveries were of birds ringed on the Grasøyane at Ulstein, and 26 of 31 were recovered along the coast of Møre og Romsdal. Three recoveries were made in Sør-Trøndelag, one in Sogn og Fjordane and one at Hordaland, indicating that the Black Guillemot may disperse along the coast outside of the breeding season, although migrations are uncommon.

Two Black Guillemots from northern Norway (Andøya and Senja) have been recovered in the influence area. None of the Black Guillemots ringed in Norway have been recovered in foreign countries and vice versa.

Winter

The Black Guillemot is associated with coastal areas, and several areas within the realm of this investigation are among the most significant wintering grounds for the species, particularly Froan and Vega.

Experiences with previous oil spills along the Norwegian coast (Helgeland coast, Røv 1982) indicate that Black Guillemot are especially vulnerable to oil contamination. Therefore mapping of distribution and population studies are required to obtain a better basis for evaluating the effects of oil contamination on population levels.

PUFFIN *Fratercula arctica*

Breeding

The Puffin is the most abundant seabird species in Norway, with a total population of more than one million pairs. They breed along the entire coast from Rogaland northward, usually in very large colonies (Røv 1984, see also Fig.5.6.1).

The colony at Runde is the largest in southern Norway, and is roughly estimated at 75,000 pairs (Fylkesmannen i Møre og Romsdal 1985). Two large colonies are located within the influence area: 60,000 pairs at Lovunden, and 10,000 pairs at Fugløy in Gildeskål (Røv 1984). Some smaller colonies are also found.

In common with other auk species, the Puffin is extremely vulnerable to oil contamination. During the spring, before the start of the breeding season, large flocks congregate on the sea near the colony. An oil spill at this time would mainly strike sexually mature individuals (see also comments on Guillemots).

Systematic investigation of population dynamics and reproductive biology has been carried out at Runde and Røst (Røv 1984), and also to a certain extent at Sklinna. Although these studies only began in 1980, a significant declining trend is already indicated by figures from Røst, and suggest serious reproductive failure (Røv 1984). It is difficult to make any concrete statement about Runde and Sklinna, but developments appear to have stabilized in both areas. Sharp declines are reported for Lovunden.

Apart from during the breeding season, little is known about distribution of Puffins. However, there are several indications that a significant number of Puffins from Røst and Runde may live within the influence area of the Heidrun field during short or longer periods in the year. During an excursion in April/May 1986, a number of Puffins were observed at sea near Haltenbanken (see section on seabirds at open sea).

Migrations

In contrast with Guillemots and Razorbills, young Puffins are able to fly when leaving the colony at the end of the breeding season. They thus do not perform a postbreeding movement by swimming as in the two other species.

Nineteen Puffins ringed at Runde have been recovered. These finds indicate that birds from Runde may disperse at sea after the breeding season, but more detailed conclusions are impossible. Four Puffins ringed in Great Britain have been recovered in central Norway, indicating that other Puffin populations are also found in the area.

5.6.7 Open sea

Little data is available on birds at open sea.

In 1986 some data was collected in association with mapping of the swimming movements of some auk species. Data of Razorbills and Guillemots with youngs are discussed in the speceis account section.

Maps of Razorbills, Guillemots (including individuals with young), Puffins, Kittiwakes, Gannets and Fulmars, are shown, but the small amount of data complicates drawing any conclusions.

Two excursions were carried out in April 1986, one from 61°N to 66°N between the 8th and the 19th of April, and one from 61°N to 64°N from April 20th to 30th. Table 5.6.8 shows the number of individuals of each species observed per day. The table does not take into consideration that some individuals may have been recorded in several ten minute intervals. Maps of Razorbills, Guillemots, Puffins, Little Auks, Kittiwakes, Gannets and Fulmars are shown.

Comments on species included in the April maps

Available information is inadequate for evaluating the extent of species distribution, but a few short comments may illustrate differences in the distribution patterns of certain species. Lacking observations of Fulmars and Kittiwakes in some areas may reflect periods when these species were not recorded.

Gannet. Results suggest that Gannets are spread in a belt along the coast in April, while they have not been observed at Haltenbanken. Gannets dives after relatively large prey, and may occur in high numbers near areas of concentrated access to fish.

Fulmar. Fulmars appear to be abundant throughout all of the areas investigated in April. They wander extensively over large open sea areas, and mainly feed on plankton, smaller fish and crustaceans. They often follow fishing boats and eat rubbish and waste. In such situations they may occur in high densities, as illustrated during one survey excursion from April 24-30, which was conducted from a coast guard vessel responsible for patrolling fishing grounds.

Kittiwake. The distribution of Kittiwakes is similar to that of the Fulmar, but their numbers are smaller. High densities near the colony at Runde, confirm that they have become established in the cliffs.

Razorbill. This species occurs only infrequently at open sea in April. Most individuals were seen near the bird cliffs at Runde, where they also have established a foot-hold. Meanwhile, a few individuals have been observed northeast of Frøya, in the direction of Haltenbanken.

Guillemot. The distribution of this species is the same as for Razorbills in April, but they occur in greater numbers, possibly reflecting the larger numbers of Guillemots than Razorbills at the breeding colony at Runde. One expects that most of the auks living near Runde in April originate from this breeding population, in that the majority of Guillemots from Great Britain and the Faroe Islands have already returned to their respective colonies by that time. Guillemots have been observed far out to sea in the vicinity of the colony at Runde, and it is assumed that these individuals are related to the population in the cliffs at that time of the year. Investigations in Great Britain indicate that Guillemots visit the cliffs at 3-5 day intervals. Between visits they remain at open sea, and cover expansive areas with a considerable radius.

Puffin. Maps indicate that Puffins also congregate near the breeding colonies at Runde and Sklinna. However, large concentrations also occur to the north and northeast of Smøla and Frøya. Age groups and populations represented in these concentrations are unknown, a factor illustrating the extreme deficiencies in our existing knowledge about concentrations of seabirds at open sea.

Little auk. This species breeds in arctic areas, and results suggest that they migrate northwards to breeding grounds in May. They are seldom observed off the coast of central Norway during the last half of April.

Discussion

During the period April 8-19, 1986, the Oceanographic Institute collected data on the distribution and occurrence of Herring fingerlings and seabirds were observed simultaneously. Seabird data has not been correlated with this or other marine data, but our general impression is that greatest numbers of birds were seen where most Herring fingerlings were recorded. Correlation of this data should be a major part of a future mapping project on seabirds at open sea off the coast of central Norway. Further investigation is essential to evaluations of the significance of the Haltenbanken oil spill influence area, for seabirds living at open sea during various times of the year.

Data on seabirds washed ashore in England suggest that some chronic oil pollution from boats and associated with the petroleum industry in the North Sea, may be responsible for auk mortality (Stowe 1982, Blake et al. 1984). The extent to which this may also occur during development of the Heidrun field is impossible to evaluate.

In order that auk populations may withstand pressures subjected by increased mortality, maximum reproduction must take place. Unfortunately, the opposite seems to be the case at the present time in several colonies in Norway. Although the prognosis is not entirely pessimistic, Norwegian populations of Guillemots, Razorbills and Puffins are declining, and widespread reproductive failure has occurred over several years in association with lacking nutrient resources (see Røv 1984). Deaths due to fishing tackle represent another high mortality factor.

Severe decline in the Guillemot population of northern Norway, make the colony at Runde one of the largest remaining in Norway (see Røv 1984). This may be a reference area for occurences in colonies in Northern Norway. The potential effects of oil contamination should therefore be carefully monitored in the future.

Tab. 5.6.8 The number of individual seabirds observed daily in the period between 8.-19.4. 1986.

Date	Gannet	Fulmar	Kittiwake	Razorbill	Guillemot	Puffin	Little Auk	Area (°N)
10.4.	2	64	91		15	141	21	65°00'
11.4.		224	162	1	1	17	96	64°45'
12.4.	2	42	90	1	1	17	101	64°30'
13.4.	12	87	111	2	8	139	60	64°15' - 64°00'
14.4.	15	25	6	8	8	216	17	63°45' - 63°30'
15.4.	13	30	39		13	72	21	63°30' - 63°00'
16.4.	4	223	47	1	17	82	6	63°15' - 62°45'
17.4.	29	113	75	30	74	727		62°45' - 62°30'
18.4.	12	53	242	5	17	56		62°30' - 61°45'

5.6.8. Summary

This report summarizes data concerning coastal seabirds and the seabirds at open sea within the influence area of the Heidrun field at Haltenbanken. The report is mainly based on information which is stored in the data base of the Seabird Project of the Directorate for Nature Management.

The geographical area comprises the coastline between Ålesund and Bodø, but some data from Runde at Herøy in Møre og Romsdal County and the islands of Røst and Værøy in Nordland County are also included.

The species account

Short discussion of species which are particularly vulnerable to oil contamination.

Divers and Grebes.

These species are relatively few in number when compared with most other seabird species. Individuals are usually solitary, dive frequently, and are difficult to observe on the water. Results therefore represent minimum numbers.

Several species wintering within the inverstigation area are relatively abundant, especially the Red-throated Divers, Great Northern Diver, White-billed Diver, and the Red-necked Grebe. These species are exceptionally vulnerable in the event of an oil spill.

Cormorant

Today the most important breeding areas for Cormorants are located in outer archipelago in Trøndelag and on the coast of Helgeland. About 70% of the Norwegian population of Cormorants breeds in the influence area. It is easily disturbed during the breeding season, and quickly abandons the nesting area upon the approach of humans, as in a clean-up operation after an oilspill.

Cormorants spend parts of the day at resting and roosting places, and are therefore regarded as less vulnerable to oil contamination. However, they may become vulnerable if they by disturbance are driven away from the skerries and into an oil slick.

Shag

The most important Shag breeding area is located in Sunnmøre, and with the colony at Runde as one of the two largest colonies in Norway. A large percentage of these birds winter within the influence area. Several smaller colonies are found on Froan, and Leka and Vega are the most important breeding localities on the coast of Helgeland.

Few Shags migrate out of the country during the autumn. The most central wintering areas at the present time appear to be located in outlying coastal areas of Nord-Møre and Sør-Trøndelag counties, where Shags from Sunnmøre, Trøndelag and Nordland congregate. Froan Nature Reserve is an important wintering area, as are several areas along the coast of Helgeland.

In common with Cormorants, Shags spend part of the day at resting or roosting places (see comments on Cormorants).

Greylag Goose

Greylag Geese breed in the archipelago from Vestlandet as far north as Finnmark. The greatest numbers are found in Møre og Romsdal, Trøndelag and at the coast of Helgeland.

Greylag Geese moult from the end of June until the end of July. Crucial moulting areas are located along the coast from Smøla and Froan to the coast of Helgeland including Vega.

The most important moulting areas for Greylags is Froan Nature Reserve and the Helgeland coast including the island of Vega. A significant population of Greylags would be threatened if an oil spill struck the coast near Froan or Vega during the moulting period. The moulting population is probably mainly comprised of Norwegian birds, but may also include geese from other countries.

Eider

Eider live near the sea during their entire life cycle, and breed along the Norwegian coast. The entire population is estimated at from 70 - 100,000 pairs. These numbers are probably far too low.

Froan Nature Reserve is without doubt the most important moulting area for Eider in Norway. A total of 36.000 Eiders, mostly adult males, was recorded in Frøya municipality in 1985. This number is considerably higher than the number potentially recruited from the local breeding population, and the extent of Norwegian and/or birds originating from other countries is unknown.

12.000 Eiders were registered at Vega in 1985. Statistics from an early count in this area (the first half of July) probably represent minimum numbers, although these numbers were also higher than that potentially recruitable from the local breeding population.

The Eider is the most abundant coastal seabird species in Norway during the winter. Counts within the influence area revealed numbers of about 140.000 individuals. The Eider is evenly distributed along the coast, and is especially numerous on Vega (winter population about 25.000), Froan, Ørlandet and outer Vikna.

A large winter population has been documented in the survey area. Their distribution contrast with that of the moulting period, emphasizing the inadequacy of our current knowledge about Eider populations found along the coast at different times of the year. Further research is required in order to carry out comprehensive consequence analyses on the population level.

King Eider

King Eider is a high arctic species which does not breed in Norway. This species winters in northern Norway, and are particularly numerous at Røst, and may regularly winter as far south as Sør-Trøndelag county. The survey area lies on the outer limits of the normal winter distribution of this species, although they may occur to av varying degree from year to year.

Velvet Scoter

Velvet Scoter is a marine species outside the breeding season, during which it exhibits flocking behaviour and has a very localised distribution. It is one of the least abundant of the sea ducks, and is considered very vulnerable to the effects of oil contamination.

The moulting population of Velvet Scoter in the influence area is outstanding in Europe, and is comprised of a minimum of 11.000 individuals.

Ørlandet, with 7.000 individuals recorded in 1985 and a minimum of 5.000 in 1986, is the most significant moulting site for Velvet Scoter in Norway. Their numbers in this area appear to have increased. The Island of Vega is the most important moulting area for Velvet Scoter in Nordland county, although the population there seems to have declined.

The most important wintering areas are Ørlandet, inner parts of Frøya, Tarva at Bjugn, Outer Vikna and Vega.

Long-tailed Duck

Long-tailed Duck breeds and moults near freshwater, but lives in marine habitat during the rest of the year. The species is evenly distributed throughout the influence area, and does not occur in any particular large concentrations. Long-tailed Ducks are often found far out to sea, and some may have been overlooked during counts. The species is considered very vulnerable in the event of an oil spill.

Red-breasted Merganser

Mapping of moulting Red-breasted Mergansers was only given priority on Frøya. The total number represented is therefore an absolute minimum. Their documented numbers are however among the highest in Europe, with a moulting population of approximately 10.000 individuals. Birds congregating within this area, probably originate from a substantial part of their breeding range in Fennoscandia.

Existing data indicates considerable variation between the results from 1974-1980 and those from 1985, suggesting a significant population decline.

The winter population constitutes a sizable part of the European population. The origins of those populations occuring along the Norwegian coast are unknown.

Auks

The Puffin is the only typical cliff breeding species breeding within the influence area for oil contamination from Heidrun. The largest colony is located at Lovunden on Lurøy.

Large colonies of Guillemot, Razorbill and Puffin breed at Runde and Røst, and Puffins also breed at Sklinna. Birds from Runde and Røst may move into the influence area outside the breeding season, mainly at open sea.

The swimming migrations of Guillemots and Razorbills away from the breeding colony are of significance. During a 40 - 50 day period, moulting adult birds and their young are incapable of flying, and are therefore extremely vulnerable to oil contamination. Little data is available for the influence area of the Heidrun field. However, available data indicates that an oil spill from Heidrun may reach areas which transect the swimming migrations of adult Guillemots accompanied by young on their way from Runde. It is uncertain whether other populations my also be affected, but the possibility that bird populations from Great Britain and the Faroe Islands migrate to and through the influence area at open sea may not be entirely ruled out. Without comprehensive information concerning swimming migrations we are not able to evaluate the impact of oil contamination for these seabird populations.

The influence area appears to be a wintering area containing resources which support birds from several colonies. However the existing data base is inadequate for making any conclusions about potential impact.

Typical bird-colony species such as the Guillemot, Brünnichs Guillemot, Razorbill, Puffin and Little Auk, mainly winter at the open sea. Some concentrations have been found near land, and are probably the result of unusually rich sources of food in these areas. Mapping of these species at sea should be undertaken, before the consequences of an oil spill can be fully understood.

The Black Guillemot is associated with coastal areas, and several areas within the realm of this investigation are among the most significant wintering grounds for the species, particularly Froan and Vega. The Black Guillemot is extremely vulnerable in the event of an oil spill.

Migration

A rough comparison of recoveries of ringed seabirds indicates that birds from several populations winter within the influence area. Existing material is not adequate for evaluating the composition of these seabird populations, or the extent to which certain populations may be affected in the event of an oil spill.

Seabirds at Open Sea

Little data is available, but existing data does indicate that Haltenbanken is an important area for several seabird species outside of the breeding season.

Important Seabird Areas

There are ten localities which immediately stand out as particularly important seabird areas (Fig. 5.6.19.), and these should be given priority in the event of an oil spill.

AREAS:

1. Runde
2. Ytre Romsdal
3. Smøla
4. Frøya incl. Froan
5. Ørlandet and Bjugn
6. Ytter-Vikna
7. Sklinna
8. Sør-Helgeland incl. Vega
9. Lovunden
10. Røst and Værøy

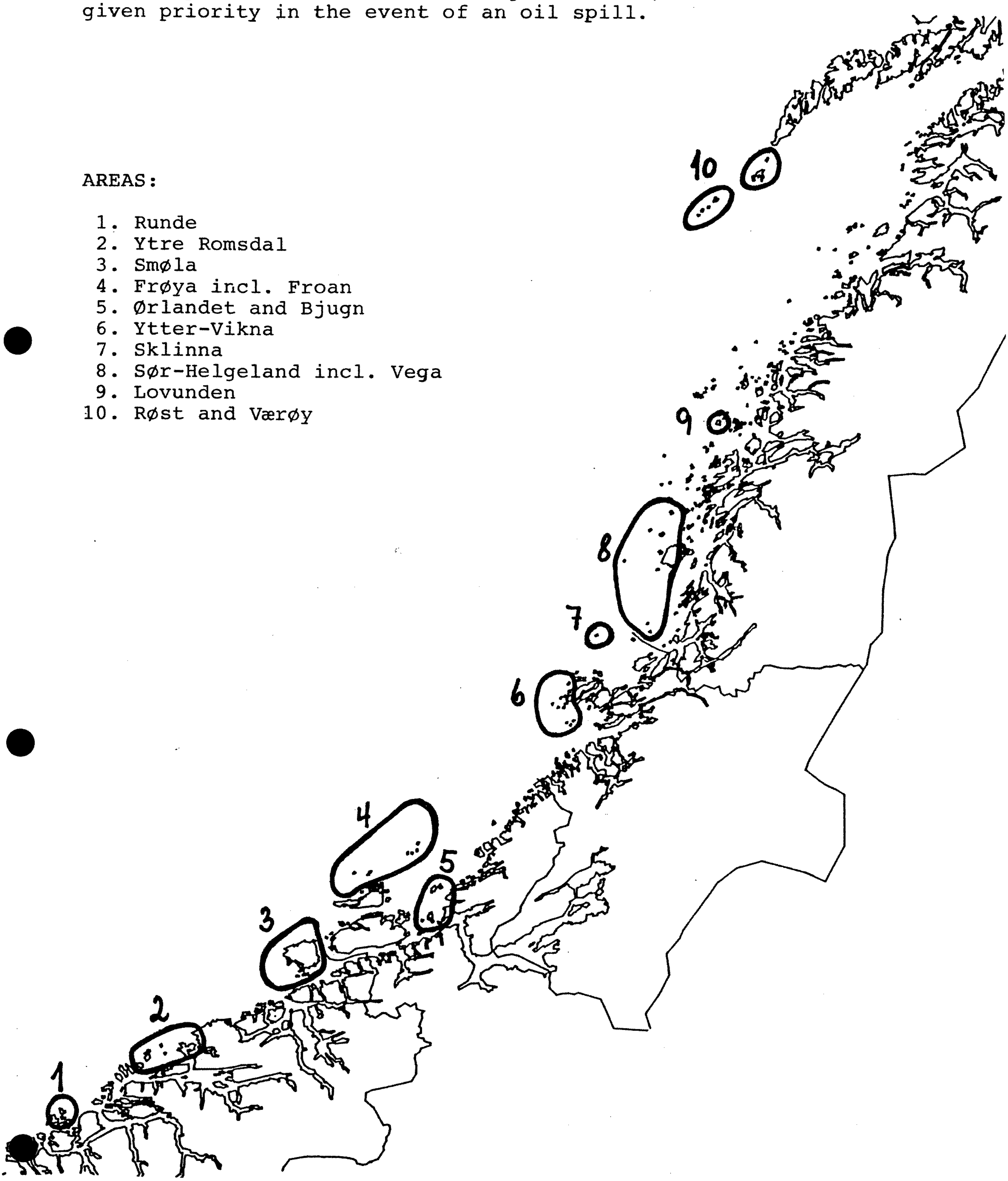


Fig. 5.6.19 The most important localities for seabirds in the possible influence area of Heidrun.

5.6.9 Impact analysis

An analysis of the impact of oil on seabird populations, should, ideally provide information on the short and long term effects of an oil spill on population levels of all vulnerable seabirds within a given area. An impact analysis thus involves evaluations of vulnerable seabird populations in inshore and offshore areas during the years degree of vulnerability, population stability, potential risk, criteria for evaluating the importance of conservation efforts concerning a particular population, effects of different types of oil and components (raw oil etc.) and measures for restricting damage from oil contamination.

Only a qualitative evaluation, based on descriptions of assumed vulnerable seabird populations relative to statistics on direction and drift obtained through simulation of oil spills, are presented here. It should be emphasized here that the data base concerning seabirds at open sea is very poor. Several simulation experiments demonstrate that these populations would be jeoparidized in the event of an oil spill at Heidrun.

This summary only discusses species which are assumed to be exceptionally vulnerable to oil contamination.

Inshore coastal seabird populations

Summer

Oil drift simulation experiments indicate an influence area which stretches from Stadt to Lofoten. Both of the Trøndelag counties and the coast of Helgeland are among the areas which are most exposed to potential stranding of oil. Several seabird colonies, some with very large breeding populations of vulnerable species, may be exposed to oil contamination. Potential damage to auks in particular should be further investigated. Although the extent of damage may vary according to stages in the breeding cycle, weather conditions etc., damage to these species may be considerable. Prior to the start of the breeding season, large, dense flocks of auks often congregate on the sea just outside of the colony. Most of these birds are reproductively active adults. If these individuals are hit by an oil spill, the long range consequences for the population would be serious. Although actual figures are not available, it is roughly estimated that if half of the breeding population of Guillemot is lost as a result of oil contamination, 50 years may elapse before the population approaches normal levels.

Later in the breeding season, young or non-reproductive individuals may reside near the colony, while breeding birds occupy the cliffs, or are away in search of food. The extent to which breeding birds may be affected by oil contamination depends on the size of the area in the vicinity of a colony through which an oil spill may pass.

Runde is the only large breeding cliff in southern Norway. Population developments appear to remain stable. Røst (including Værøy) supports by far the largest seabird colonies in Norway. Population developments have been negative for all of these species, but particularly for puffins. The Puffin population has been reduced by one-half from 1979 to 1986. The Puffin colony at Lovunden also appears to have declined radically. This colony is more exposed to potential oil contamination than that at Røst.

At Sklinna, a breakwater between two islands here may act as a kind of oil trap, and lead to extensive damage to birds on the water in the vicinity of the colonies.

During recent years, the breeding population of Guillemots in northern Norway has also sharply declined. If these trends continue, Runde and Røst/Værøy alone will support a significant proportion of the remaining Guillemot population in Norway. Therefore, these areas may serve as crucial references for population developments in other areas, and it is important that extensive oil contamination to these populations is avoided in the future.

Black Guillemots breed more dispersed than other auk species. They are often preyed upon by mink, and therefore mainly nest in outlying coastal areas, where they are ufortunately exposed to stranded oil. The greatest numbers of this species within the influence area for Heidrun, are found at Froan and Vega. Oil which strands in these areas could damage a large percent of the total population of black guillemots in Norway.

Normal helicopter and supply base activities seems to have no important effects on seabirds in any of the suggested alternatives for helicopter and supply base. Helicopter flights at low altitudes should be avoided in the vicinity of Cormorant colonies in the breeding season.

Moulting period

Moulting seabirds often congregate in dense concentrations in particular areas. Greylag Geese, Eiders and some mergansers assemble in exposed areas of the archipelago where they are vulnerable to contamination from stranded oil. Velvet Scoter usually flock in less exposed areas.

Damage to moulting duck populations may be considerable when oil strands in areas including Froan/Ørlandet and Vega. Today, these regions are significant for moulting ducks, primarily Eider, but also Greylag Geese and Velvet Scoter. During the moulting period, ducks are incapable of flying and are regarded as exceptionally vulnerable to oil contamination.

The composition of moulting flocks along the coast is unknown. Damage to moulting duck populations (local, as well as others including possible Fennoscandian breeding populations) may have serious consequences for breeding populations.

Winter seabirds

Computer simulation of oil drift and stranding reveals that potential for stranding in large areas of Sør-Trøndelag, Nord-Trøndelag and Helgeland is highest during the winter. The risk of oil contamination during the winter is higher because of the lower number of daylight hours and reduced visibility, and decreased survival after even small oil damages related to lower temperatures.

The influence area of Heidrun Field is the most important wintering area for most of the seabird species which are considered vulnerable to oil contamination, in all of Norway. A significant weakness with the available material on these species is the lack of information concerning which populations winter in the area. Evaluation of the impact of damages related to oil spills, is largely limited to the number of birds which may be affected, and to a lesser degree the long term consequences for different populations.

Divers and grebes are exposed to oil contamination. Experience from England demonstrates that species like the Great Northern Diver are exceptionally vulnerable. During one oil spill, the number of carcasses of Great Northern Divers found dead as a result of oil contamination exceeded the total number of individuals previously thought to be living in the area. The above illustrates the extreme difficulties in properly surveying these species. Information on the size of the breeding population of several of these species is limited, and it is difficult to make conclusions concerning populations in different areas.

Meanwhile all of these species breed in small numbers throughout their entire distributional range, compared with other seabird species. Therefore, a relatively significant number of birds winter in coastal regions of the influence area. Oil stranding may lead to high losses of certain species and significant reductions of the breeding population.

Cormorants winter along the coast in the entire area, with highest concentrations at Froan. Damages to cormorants here would probably affect bird originating from several areas along the coast, thereby reducing the total extent of damage to a single population. Shags are more often found in outlying coastal areas, and are therefore more vulnerable to oil contamination than cormorants. Reduction in the number of adult Shags at the colony at Runde, which has undergone serious declines and poor reproductive success in recent years, would have particularly serious consequences.

Eiders are found in inner and outer coastal areas, with greatest concentrations found in areas which are highly exposed to oil contamination. Oil stranding in Froan, Vikna or Vega could destroy large wintering populations. A high percentage of Eider in these areas occupy exposed coastline, and we have no information on which populations would experience greatest losses. Serious losses may intensify negative developments already seen in wintering populations of Eiders in recent years.

Velvet Scoter are very vulnerable to oil contamination as documented during the occurrence of several oil spills in foreign countries. Heavy losses of Velvet Scoter may be expected in the event of an oil spill stranding at Frøya/Ørlandet, Vikna or Vega. We have no information on which populations may be involved.

Long tailed ducks are very vulnerable to oil contamination, and often live in areas which are exposed to weather, and consequently, oil spills. The species is relatively abundant and evenly distributed throughout the influence area of Heidrun Field. The consequences for breeding populations, and potential losses resulting from oil contamination, are unknown.

Mergansers are very vulnerable to oil contamination, but often occur in areas which are less exposed, such as between islets and skerries. They are highly mobile, and may follow schools of fish. Therefore it is difficult to determine which populations may be damaged in the event of an oil spill. At present we have no information on which populations may be affected.

Auks are very vulnerable to oil contamination. Although they may occur in varying numbers along the coast, they are most abundant at open sea (see following section).

Offshore seabird populations

The data base for seabirds at open sea is very poor.

Oil drift simulation experiments indicate that an oil spill from Heidrun at any time of the year, will remain at open sea over shorter or longer periods of time. Therefore an oil spill will drift over large open sea areas. An oil spill at Heidrun could thereby damage seabirds at open sea. We are unable to evaluate the consequences or extent of damages on the basis of existing data.

An oil spill in the period March-May, could affect auks on their way to nesting colonies at Runde, Lovunden and RØst. Most of these individuals are breeding birds, which of course would result in immediate consequences for the rest of the breeding population.

An oil spill in July-August may affect Guillemots with young engaged in swimming migrations from Runde. These probably move through Haltenbanken, but they may remain in the area over an unknown period of time. During migrations, adults and young are incapable of flying and are therefore extremely exposed to oil contamination. An oil spill drifting over large open areas at sea could affect large numbers of auks, having consequences for auk populations from Norway, Great Britain and the Faroe Islands.

Data from one excursion in the North Sea in July 1985, indicates that significant numbers of Guillemots with young engage in a swimming migration toward Norwegian coastal waters. This information complies with results from ringing recoveries, but the migration appears to begin much earlier than previously assumed. We have no information on whether these birds migrate through areas which may be affected by an oil spill from Heidrun Field.

Seabird resources in the influence area of the "Heidrun" oil field at Haltenbanken

Map appendix

CONTENTS

1. Maps that cover the entire influence area, where data are presented according to municipality

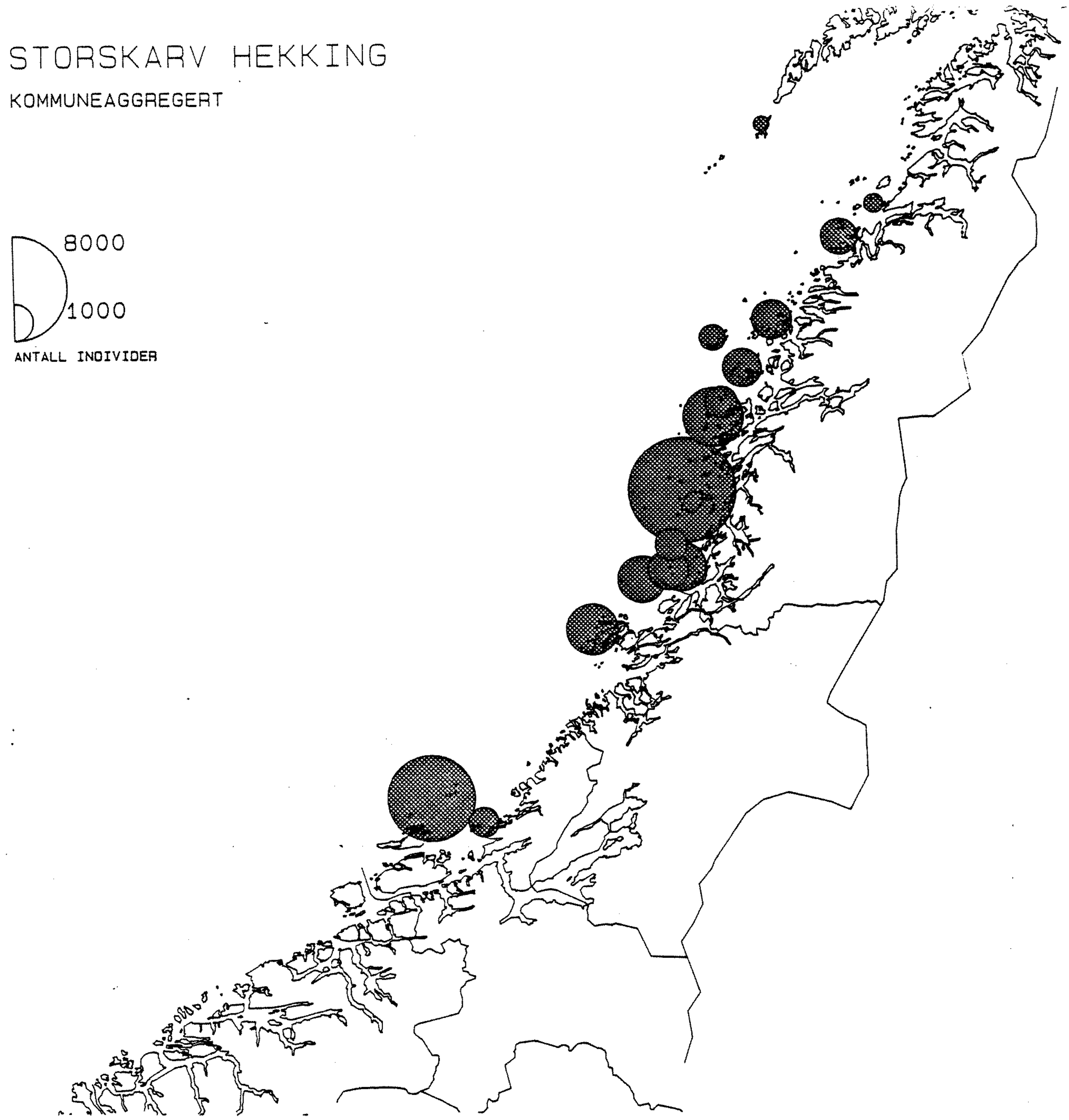


Fig. 1. 1 Distribution of breeding Cormorants <u>Phalacrocorax carbo</u> in the influence area. Scale refers to circle diameter and represents no. of individuals.

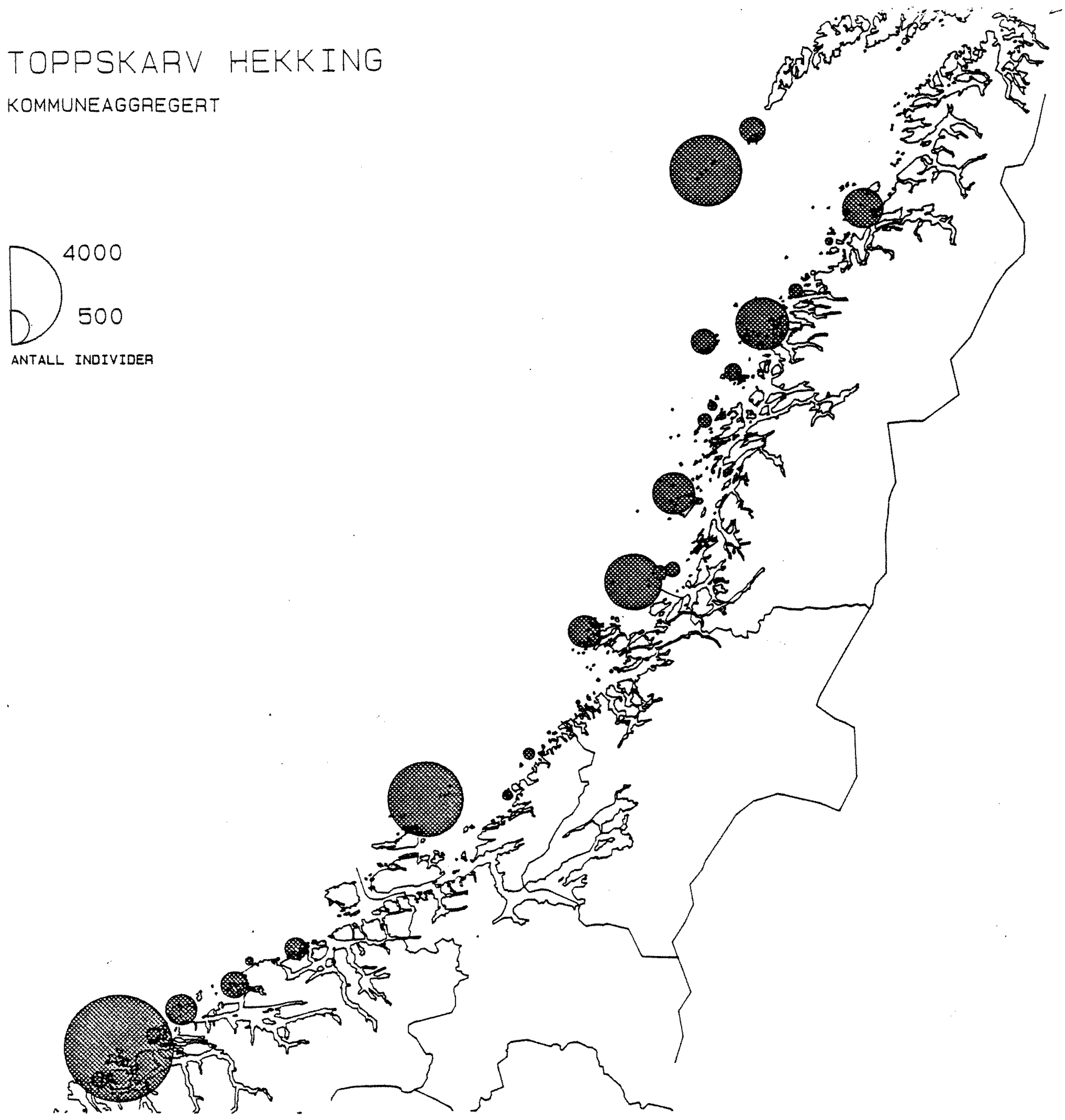


Fig. 1. 2 Distribution of breeding Shags <u>Phalacrocorax aristotelis</u> in the influence area. Scale refers to circle diameter and represents no. of individuals.

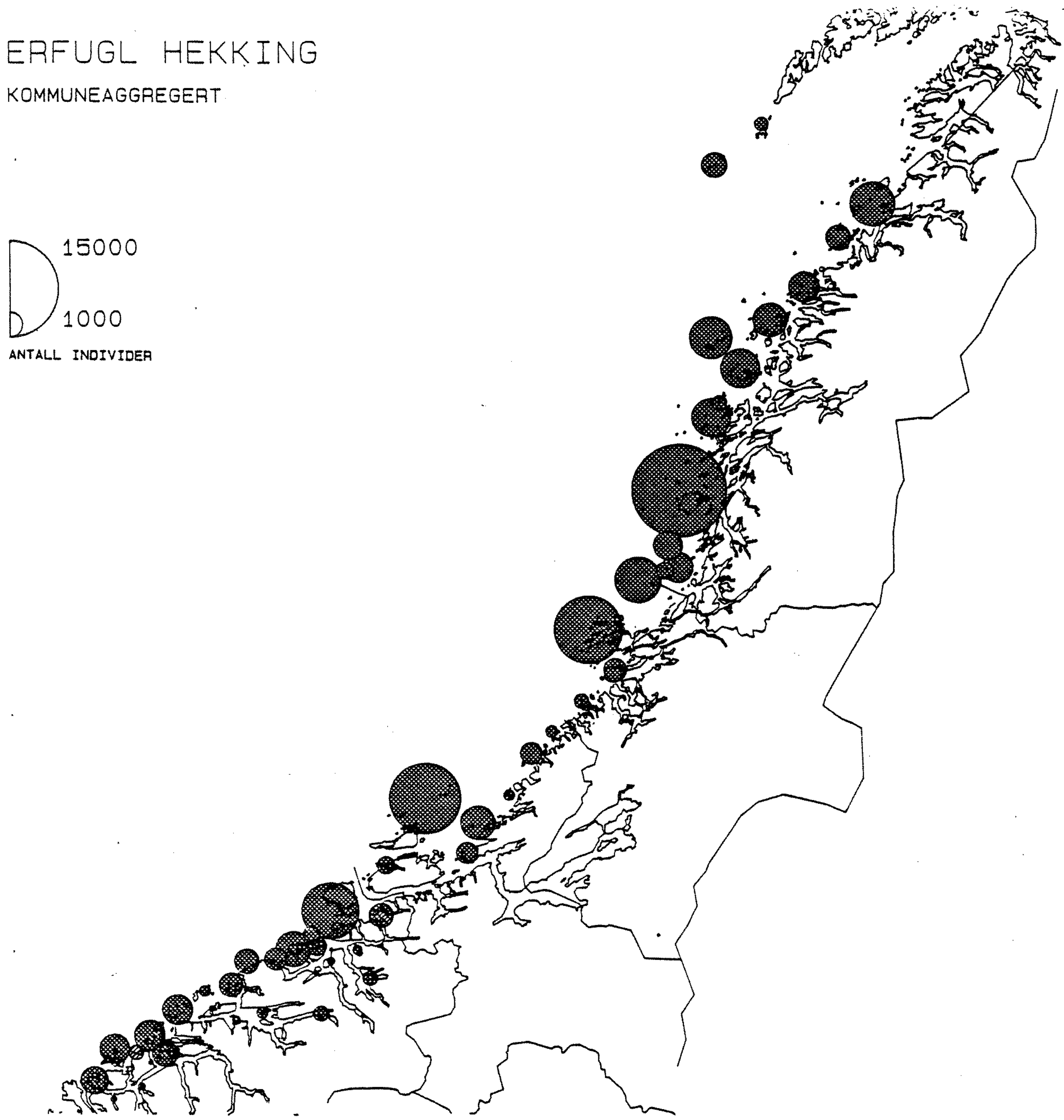


Fig. 1. 3 Distribution of breeding Eiders <u>Somateria mollissima</u> in the influence area. Scale refers to circle diameter and represents no. of individuals.

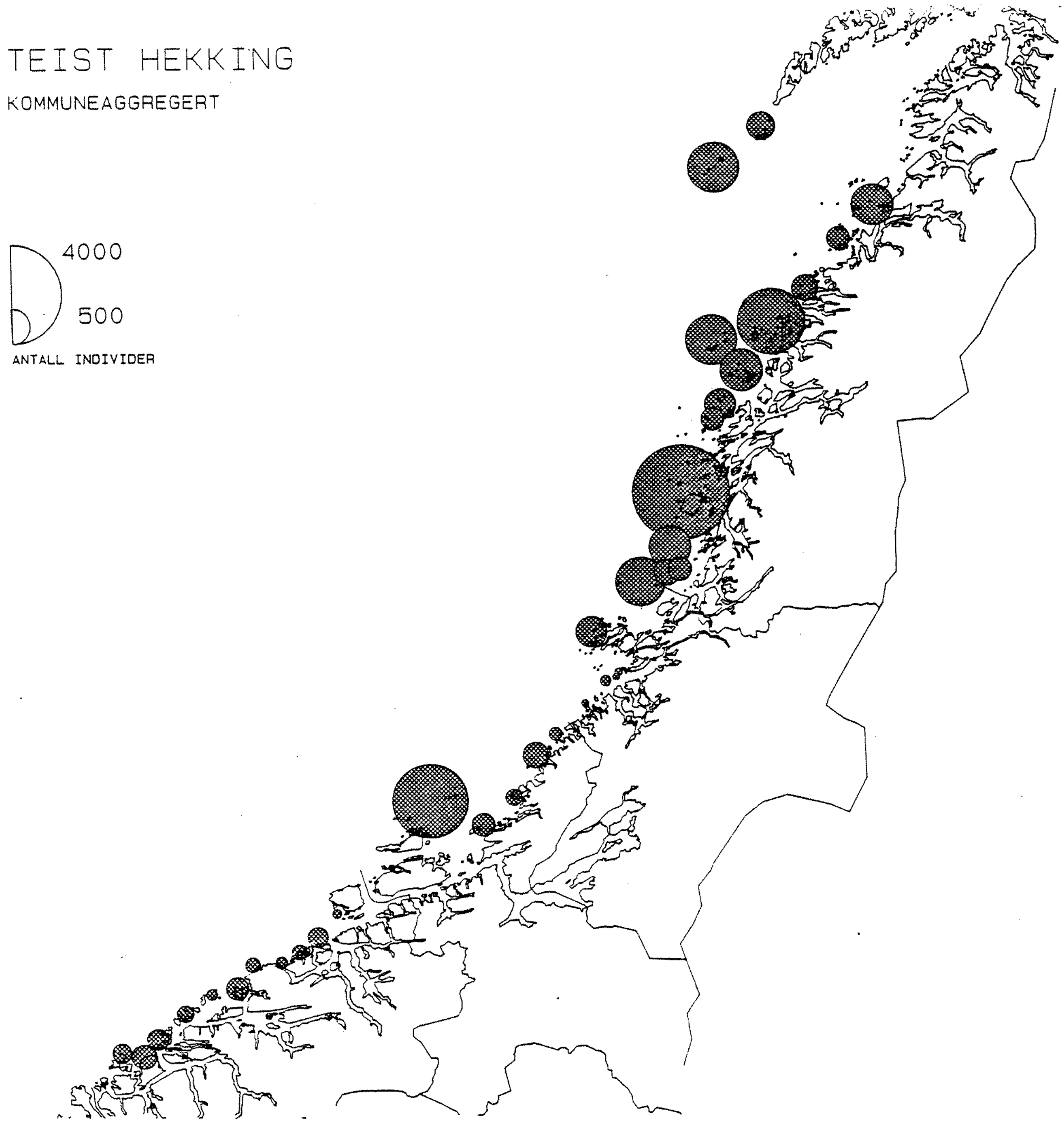


Fig. 1. 4 Distribution of breeding Black Guillemots _Cepphus grylle_ in the influence area. Scale refers to circle diameter and represents no. of individuals.

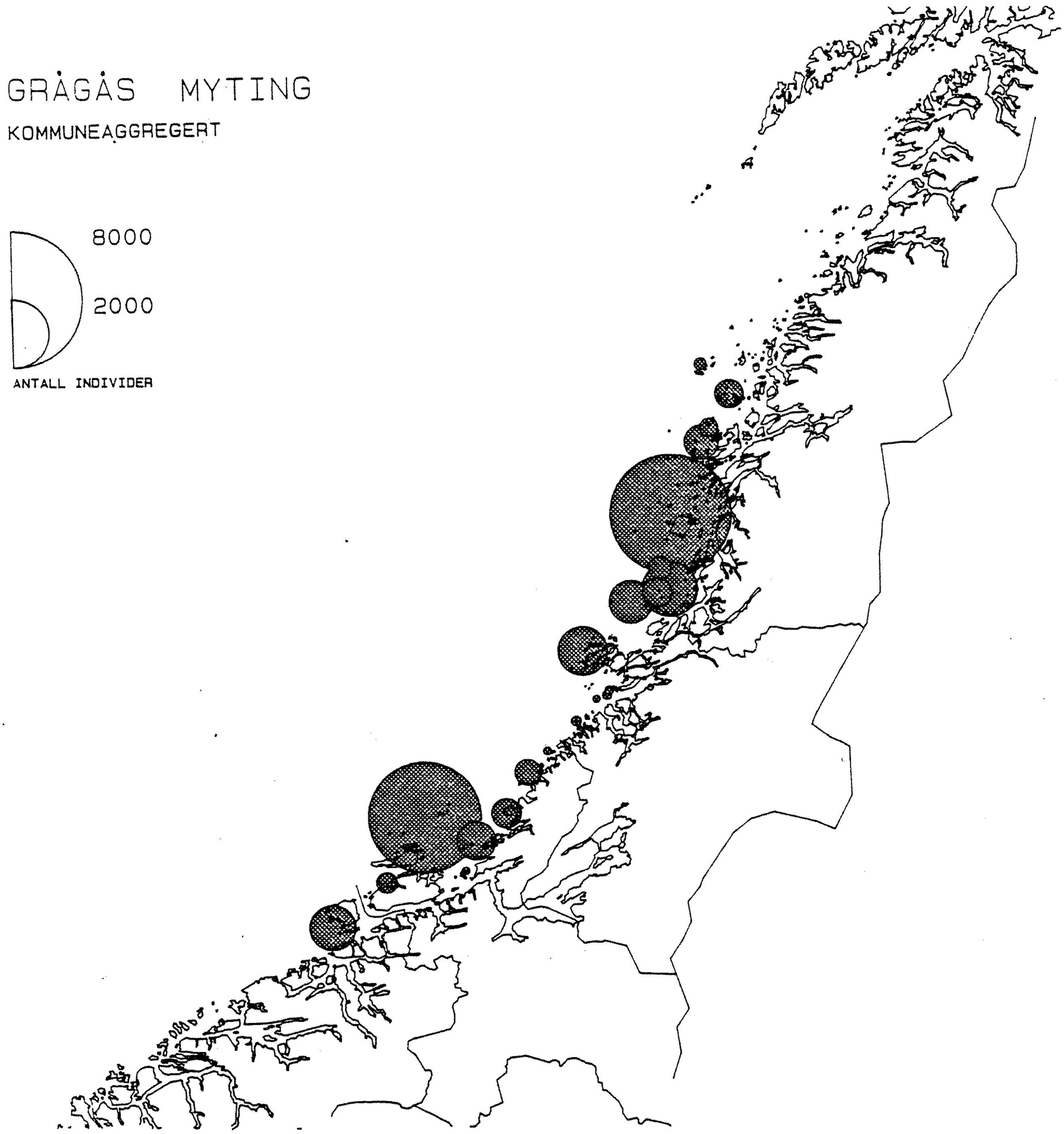


Fig. 1. 5 Distribution of moulting Greylag Geese <u>Anser anser</u> in the influence area. Scale refers to circle diameter and represents no. of individuals.

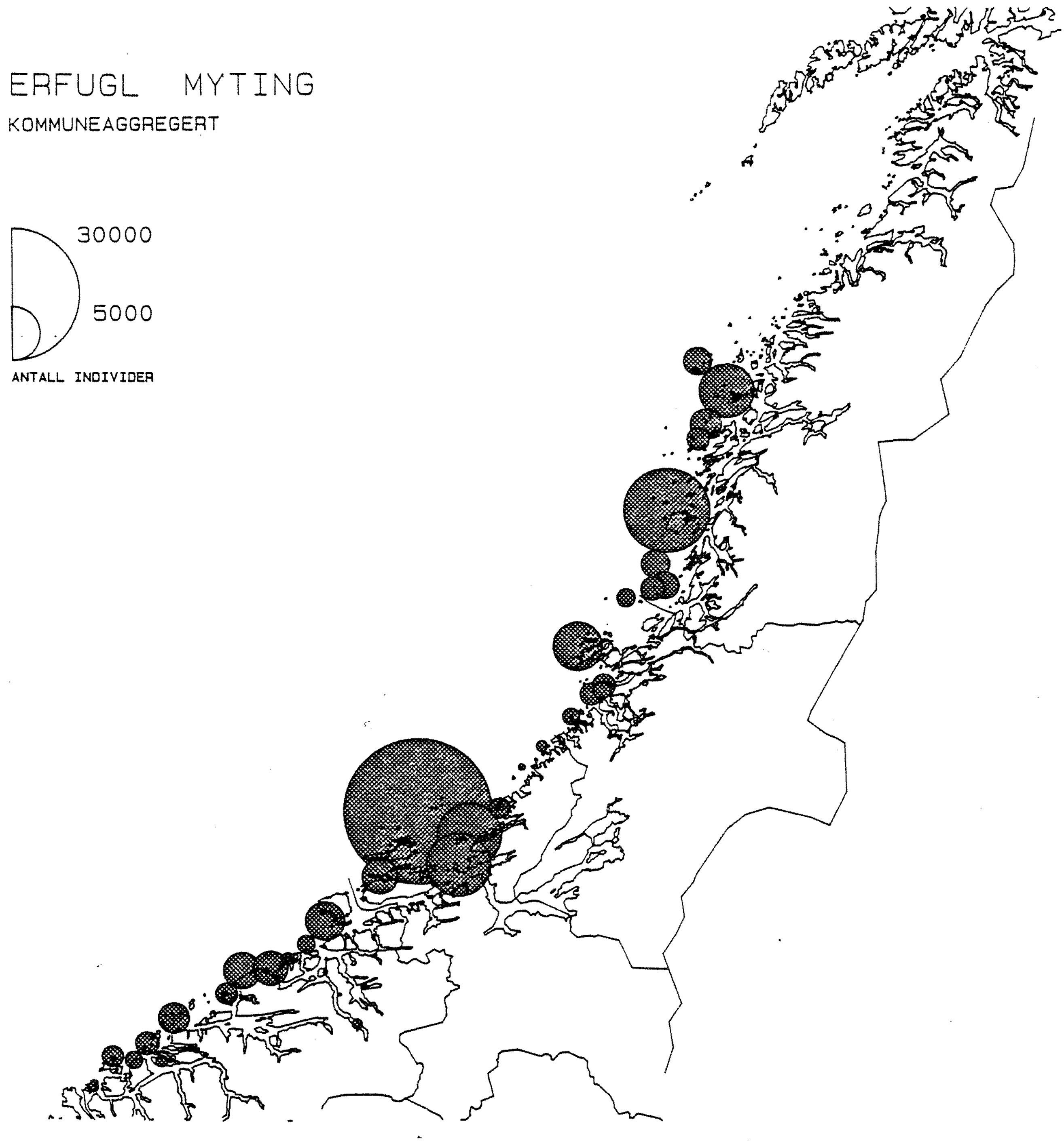


Fig. 1. 6 Distribution of moulting Eiders *Somateria mollissima* in the influence area. Scale refers to circle diameter and represents no. of individuals.

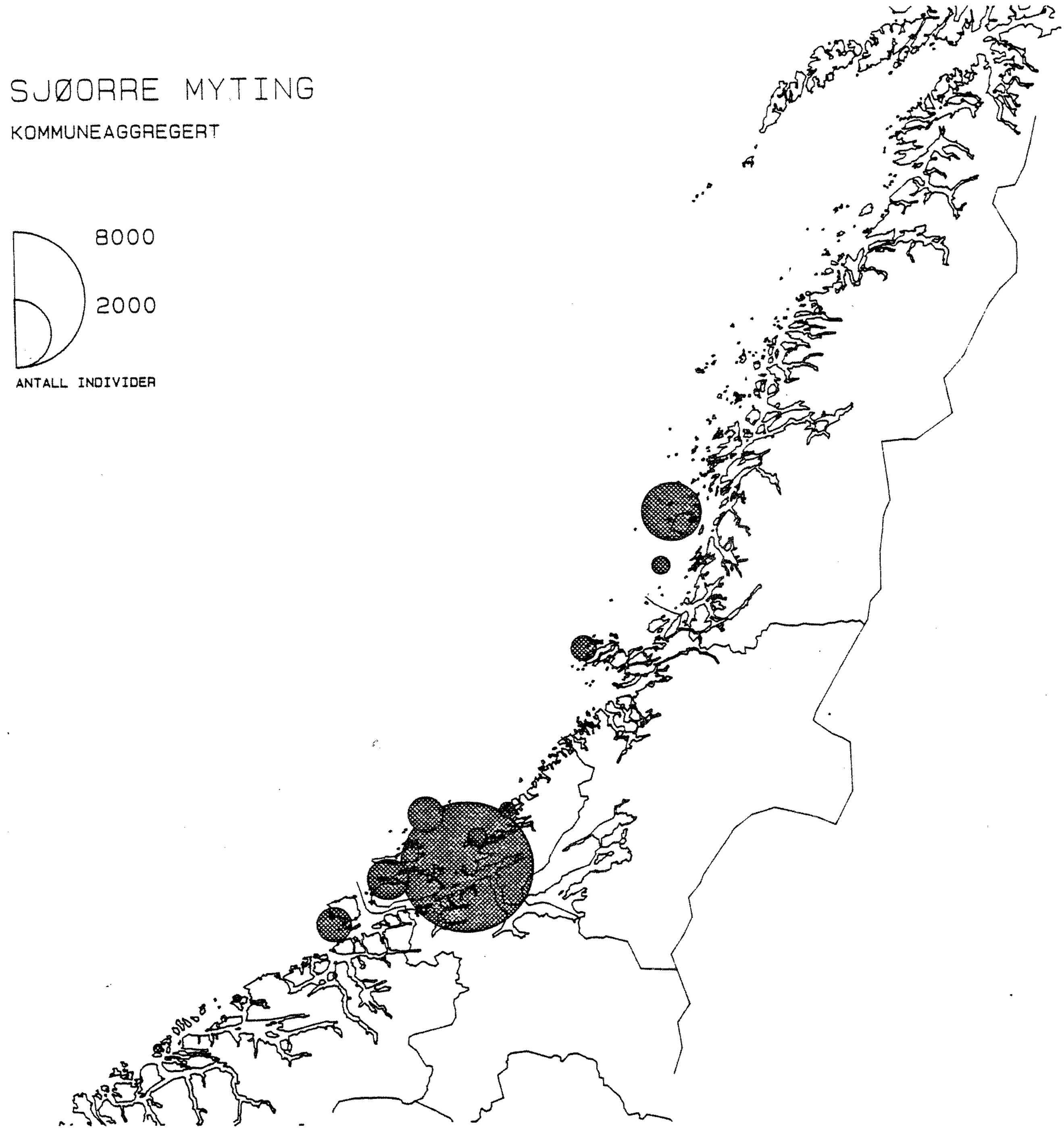


Fig. 1. 7 Distribution of moulting Velvet Scoter *Melanitta fusca* in the influence area. Scale refers to circle diameter and represents no. of individuals.

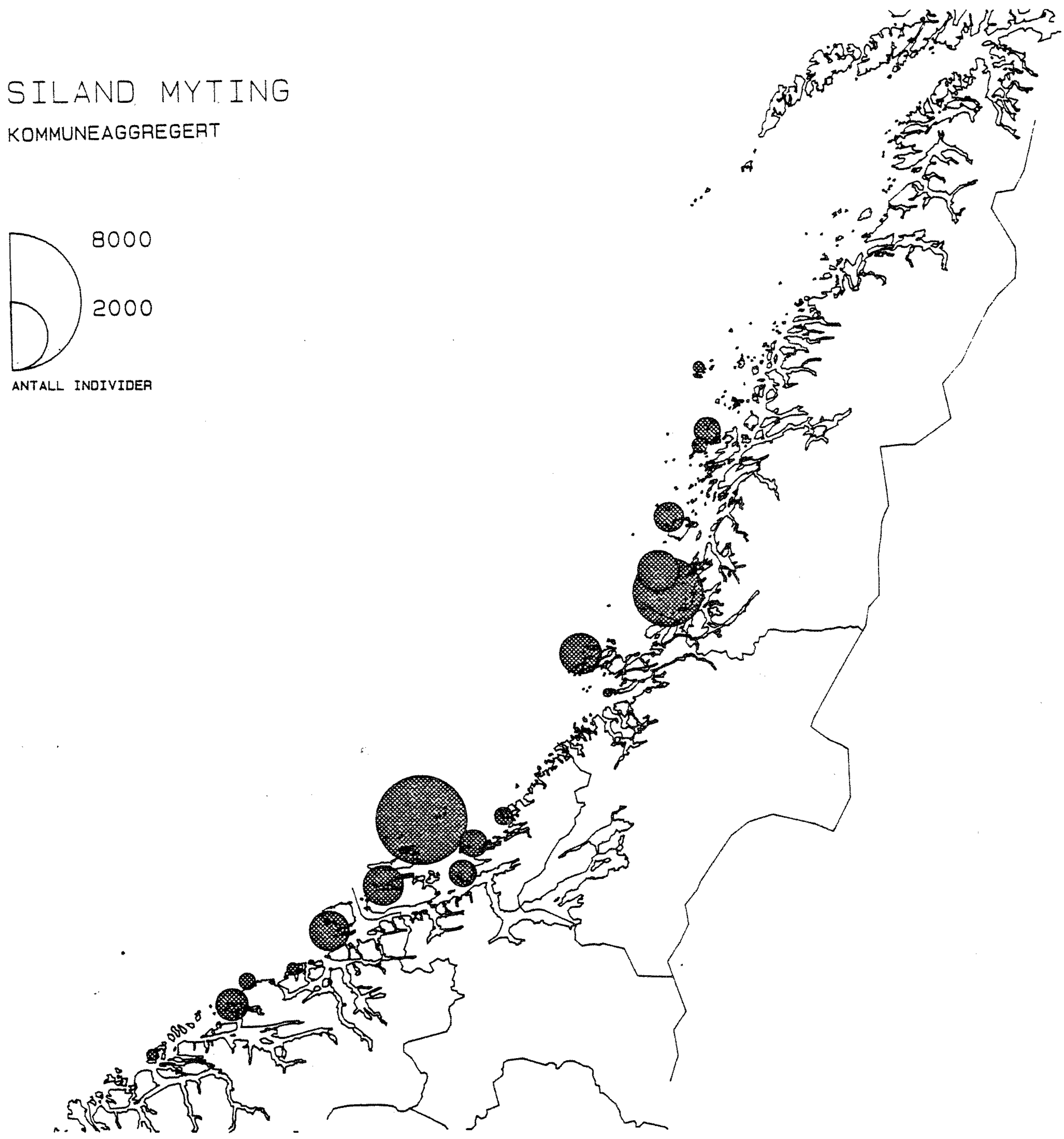


Fig. 1. 8 Distribution of moulting Red-Breasted Merganser <u>Mergus serrator</u> in the influence area. Scale refers to circle diameter and represents no. of individuals.

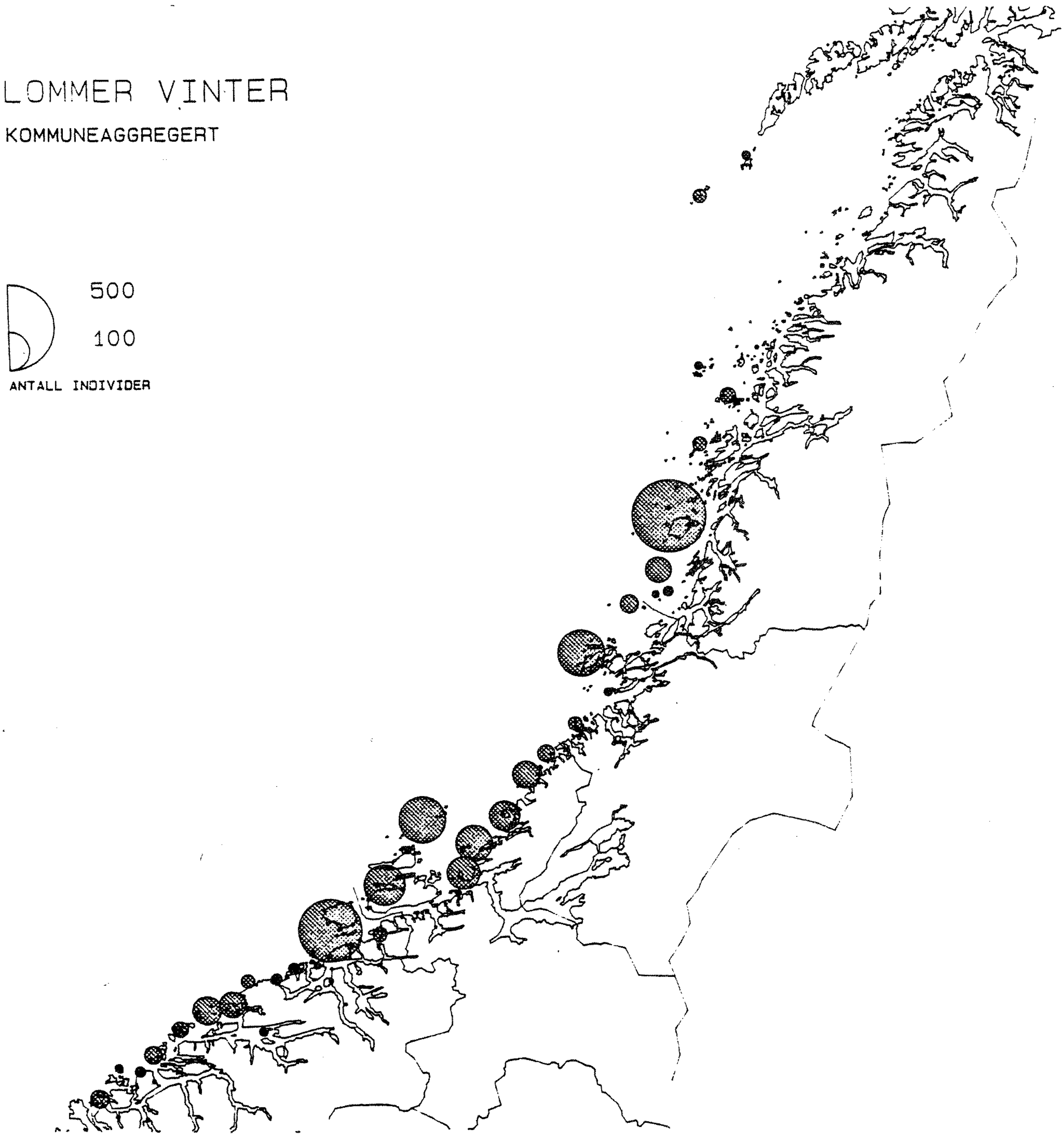


Fig. 1. 9 Distribution of wintering Divers Gavia sp. in the influence area. Scale refers to circle diameter and represents no. of individuals.

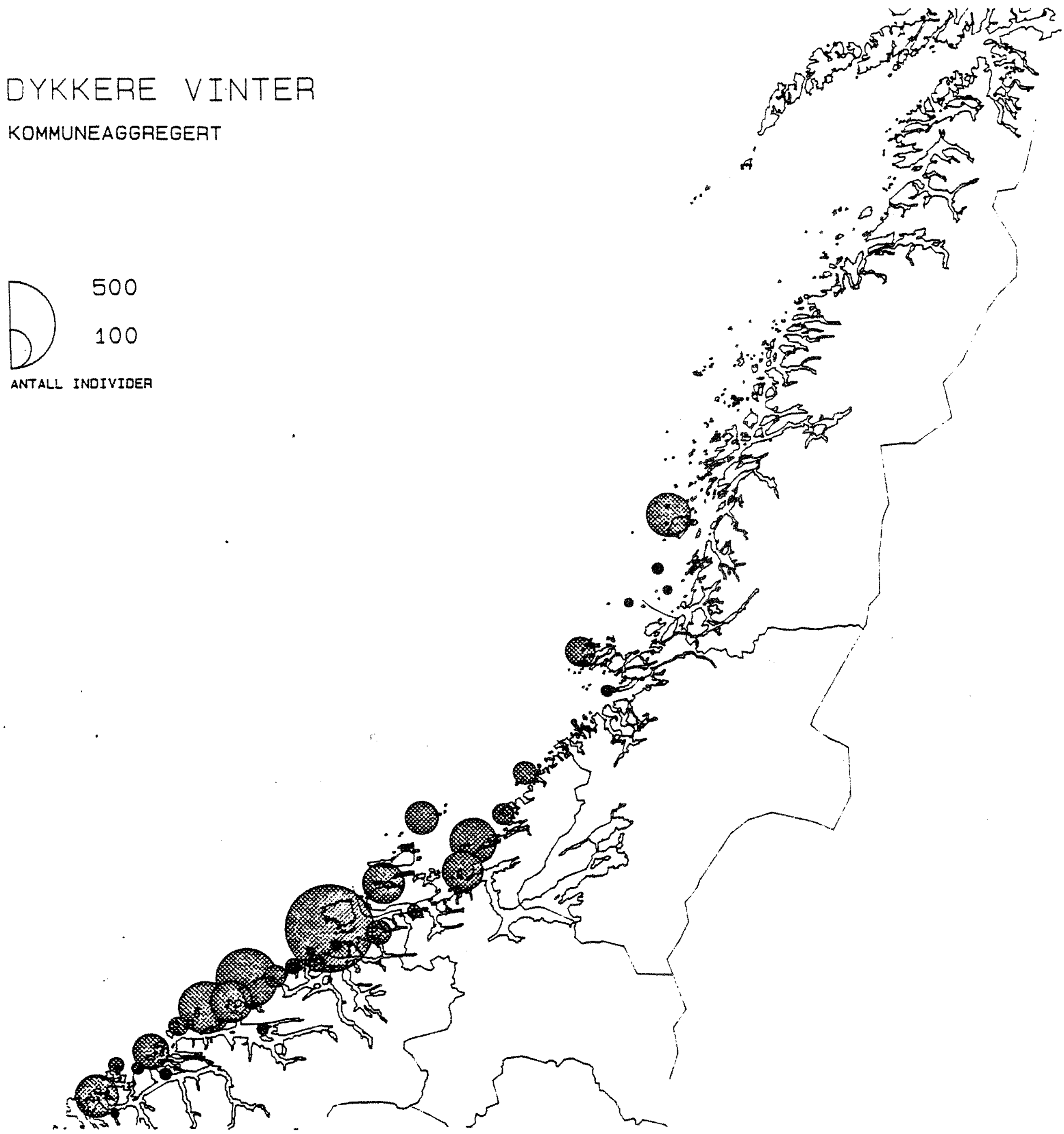


Fig. 1.10 Distribution of wintering Grebes <u>Podiceps sp.</u> in the influence area. Scale refers to circle diameter and represents no. of individuals.

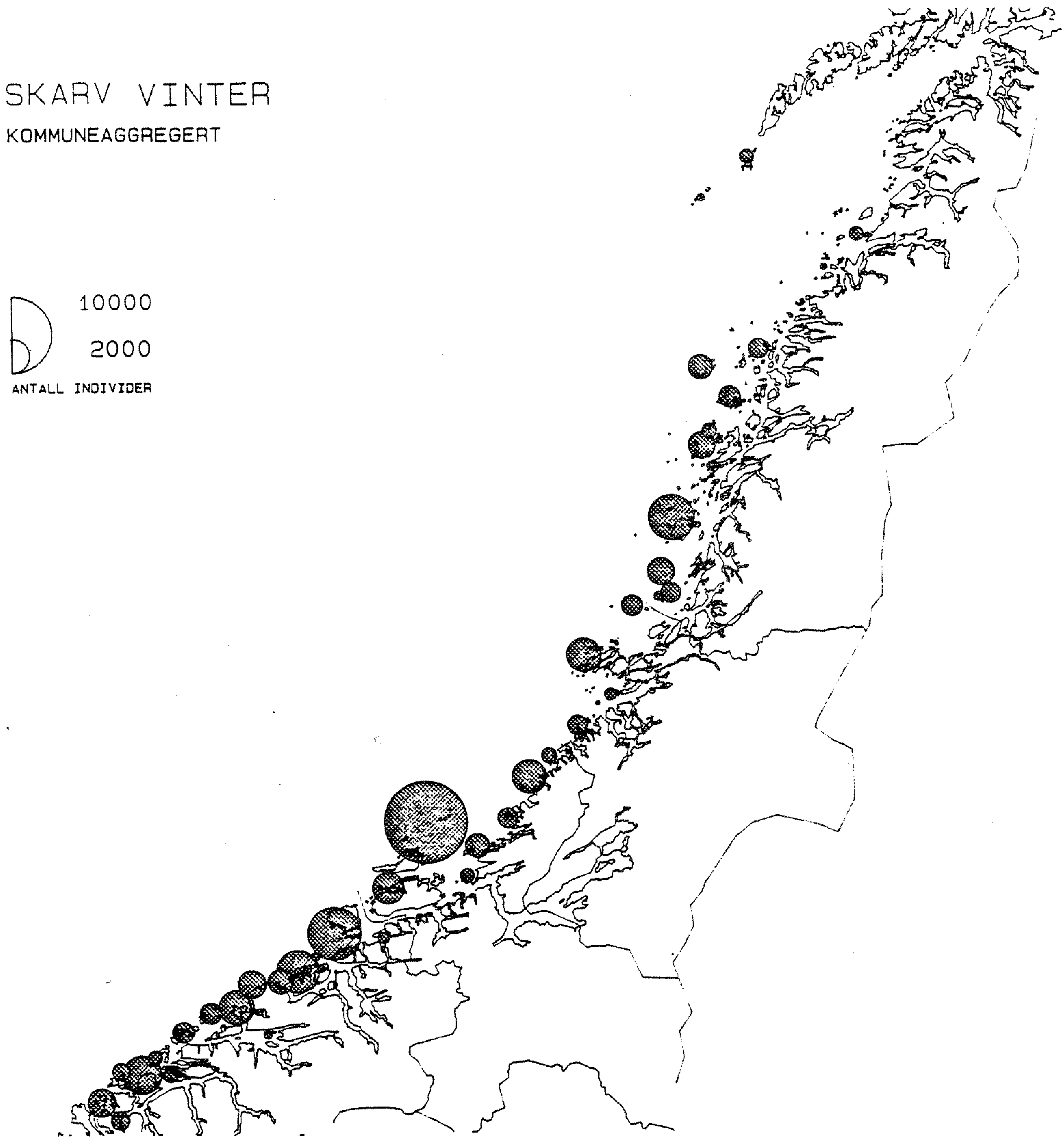


Fig. 1.11 Distribution of wintering Shags Phalacrocorax sp. in the influence area. Scale refers to circle diameter and represents no. of individuals.

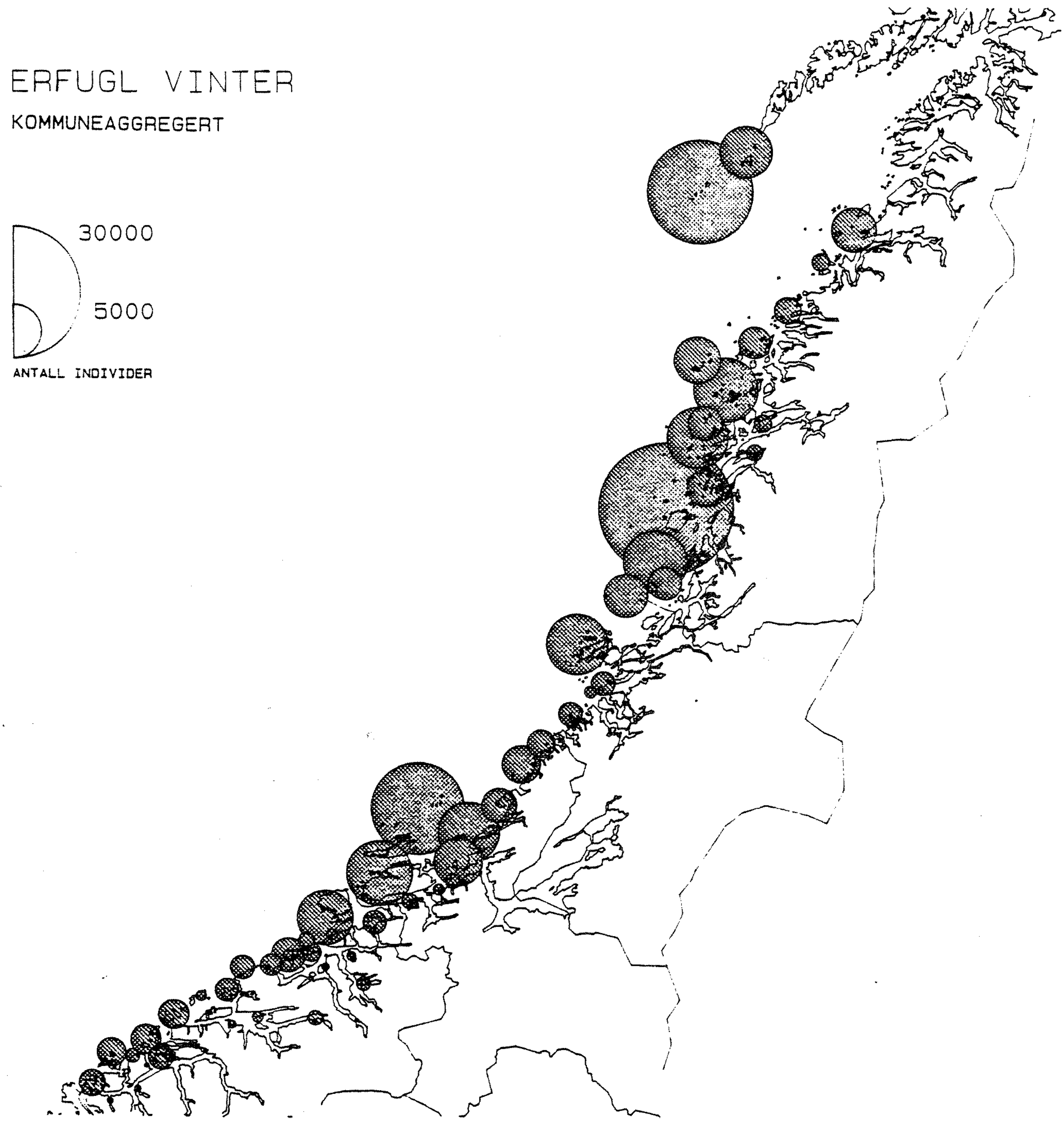


Fig. 1.12 Distribution of wintering Eiders <u>Somateria mollissima</u> in the influence area. Scale refers to circle diameter and represents no. of individuals.

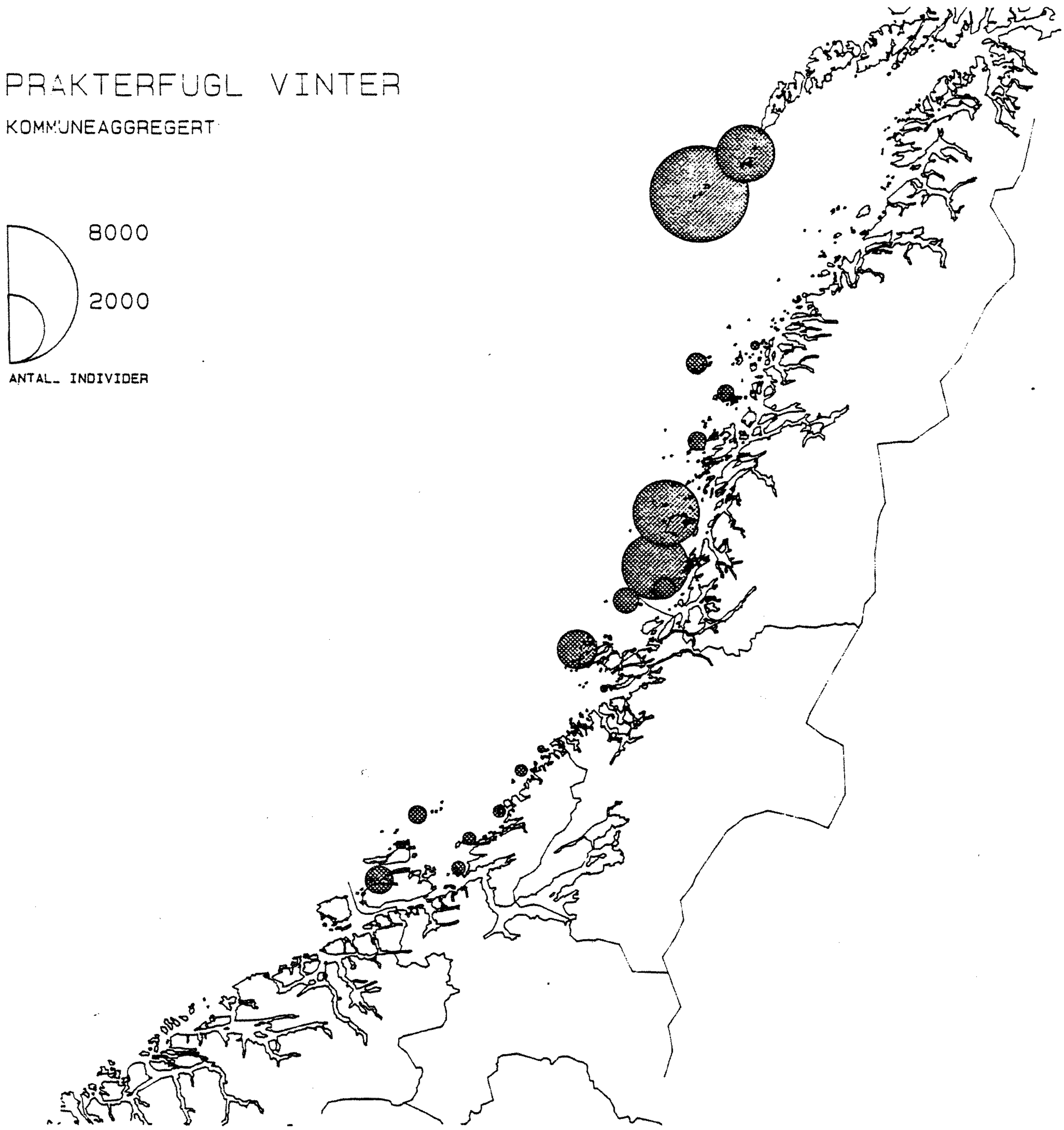


Fig. 1.13 Distribution of wintering King Eiders <u>Somateria spectabilis</u> in the influence area. Scale refers to circle diameter and represents no. of individuals.

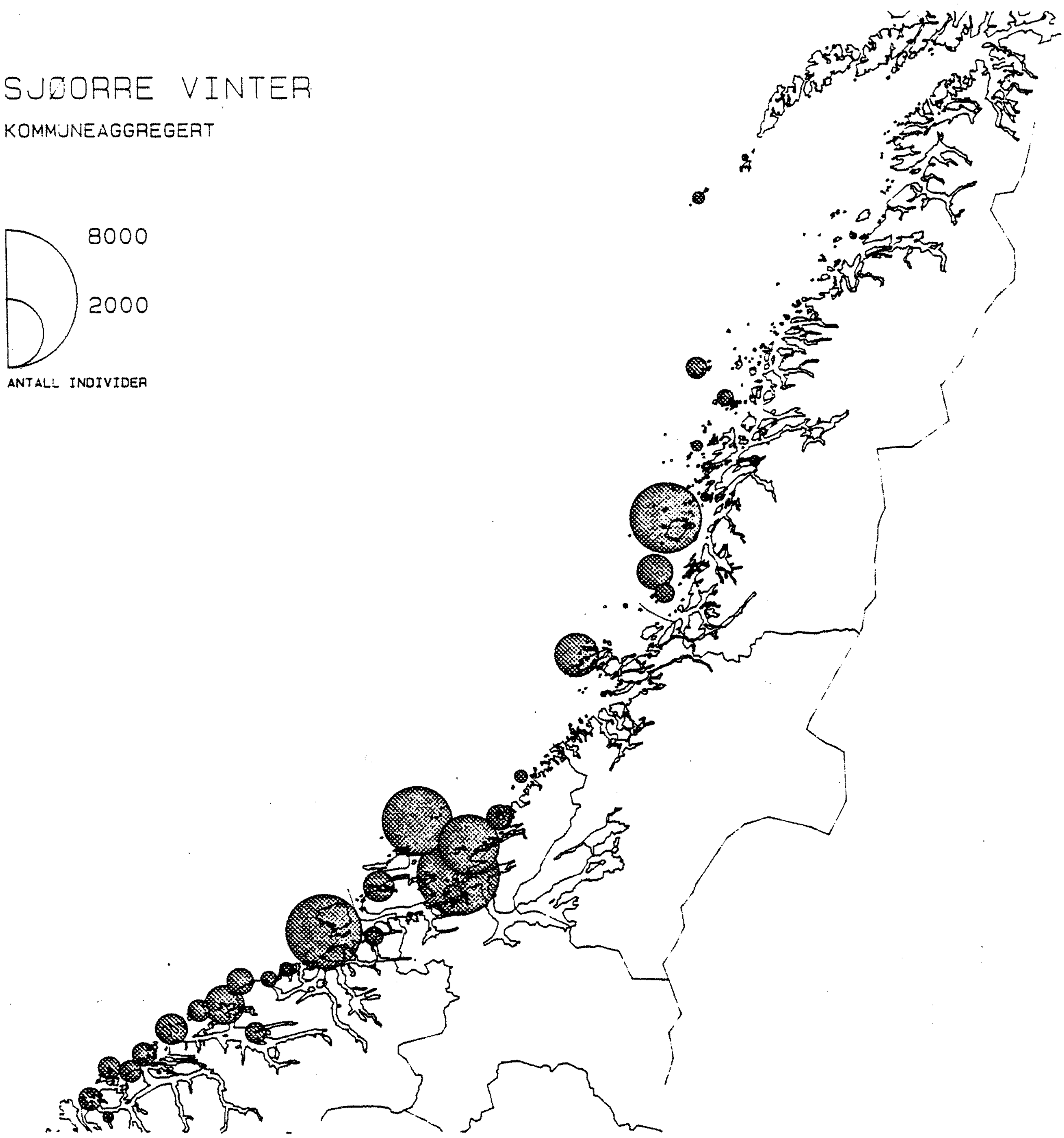


Fig. 1.14 Distribution of wintering Velvet Scoters <u>Melanitta fusca</u> in the influence area. Scale refers to circle diameter and represents no. of individuals.

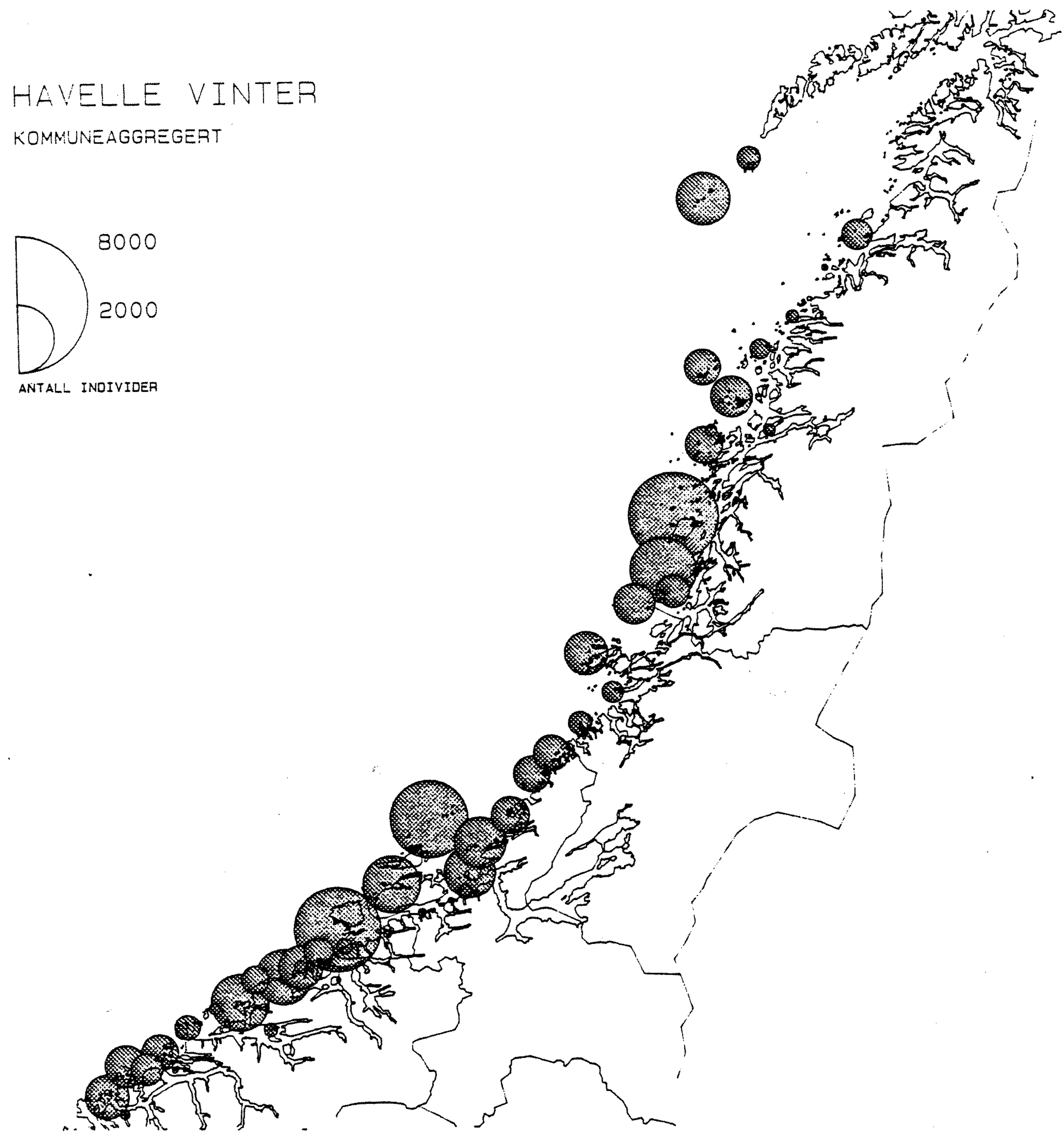


Fig. 1.15 Distribution of wintering Long-tailed Ducks Clangula hyemalis in the influence area. Scale refers to circle diameter and represents no. of individuals.

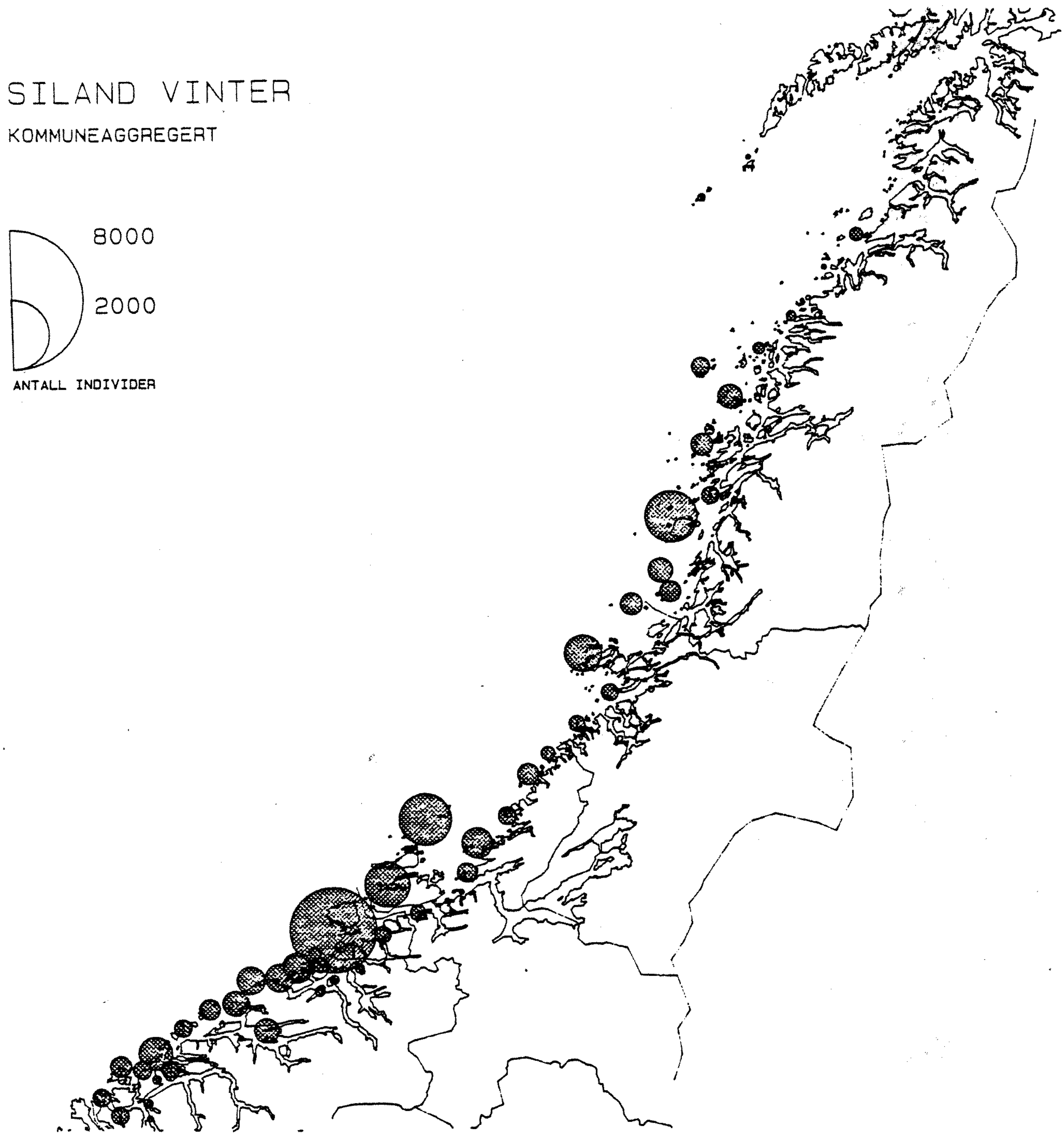


Fig. 1.16 Distribution of wintering Red-breasted Mergansers Mergus serrator in the influence area. Scale refers to circle diameter and represents no. of individuals.

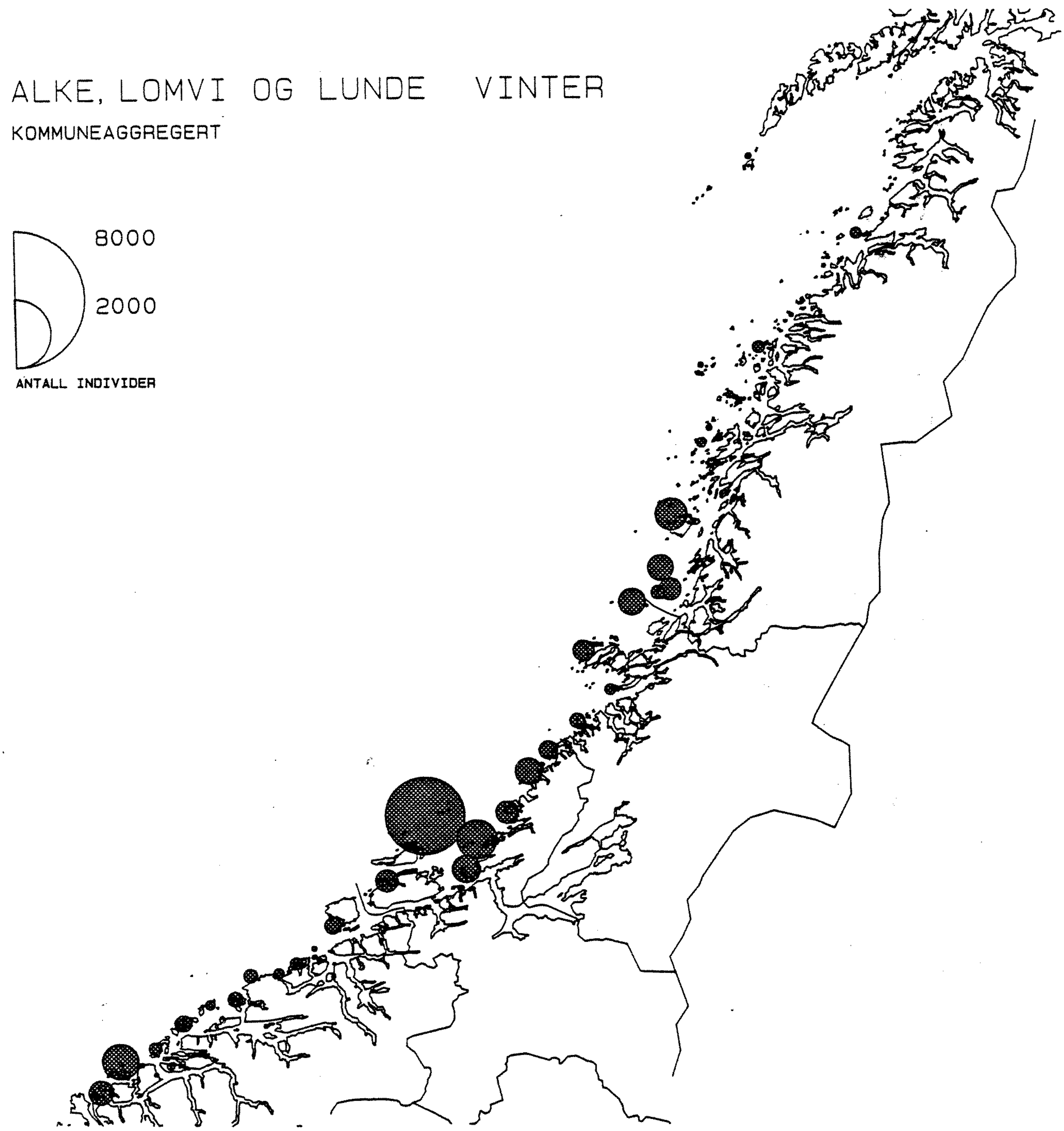


Fig. 1.17 Distribution of wintering Razorbills _Alca torda_, Guillemots _Uria aalge_ and Puffins _Fratercula arctica_ in the influence area. Scale refers to circle diameter and represents no. of individuals.

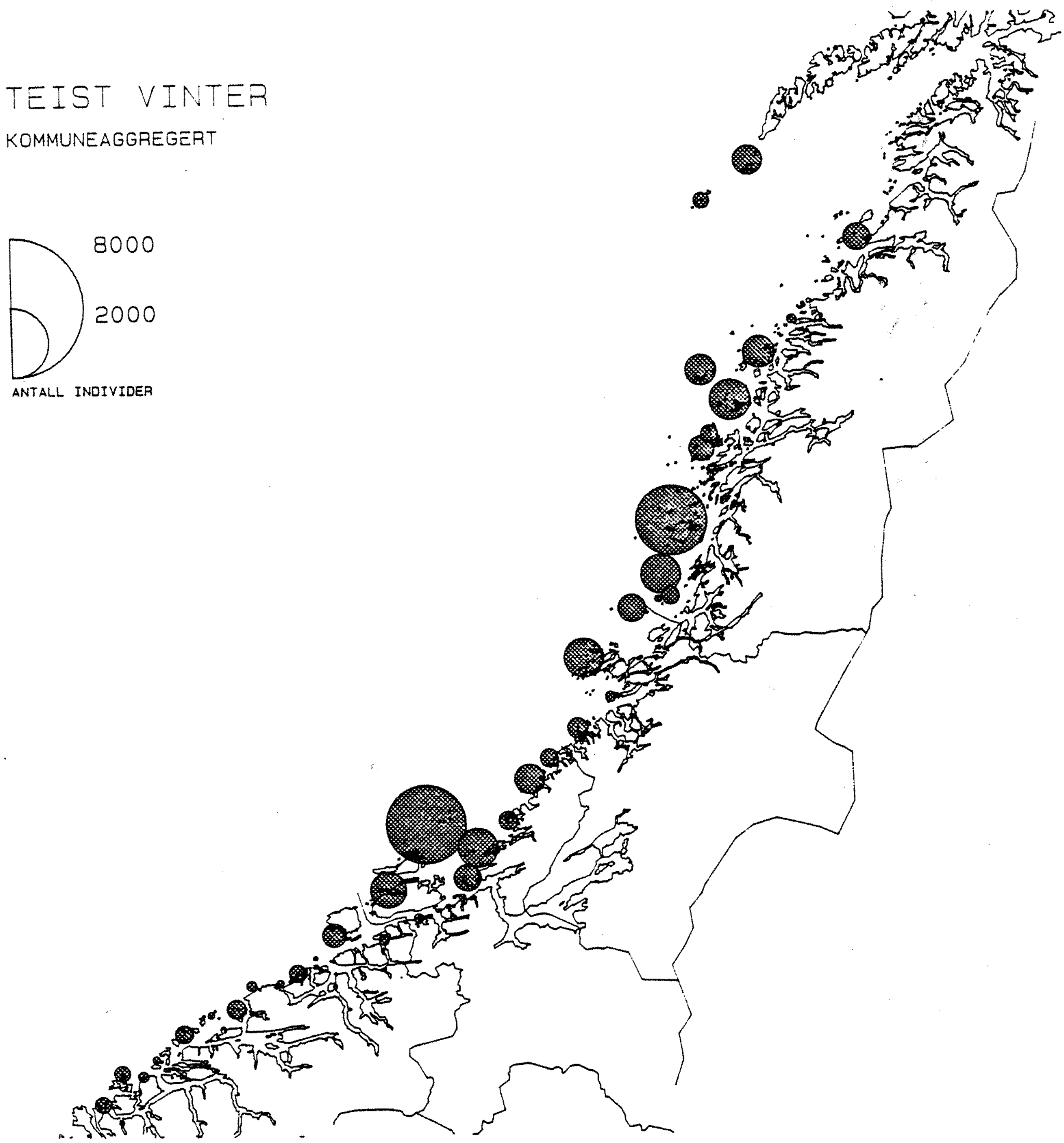


Fig. 1.18 Distribution of wintering Black Guillemots <u>Cepphus grylle</u> in the influence area. Scale refers to circle diameter and represents no. of individuals.

2. County distribution maps from Møre og Romsdal to Lofoten

	Møre og Romsdal	Sør-Tr.lag	Nord-Tr.lag	Nordland (south)	Nordland (north)
Breeding					
Cormorant		2. 2	2. 4	2. 6	2. 8
Shag	2. 1	2. 3	2. 5	2. 7	2. 9
Moulting					
Greylag Goose	2.10	2.14	2.18	2.22	
Eider	2.11	2.15	2.19	2.23	
Velvet Scoter	2.12	2.16	2.20	2.24	
Red-br. merganser	2.13	2.17	2.21	2.25	
Winter					
Divers	2.26	2.34	2.44	2.54	2.64
Grebes	2.27	2.35	2.45	2.55	2.65
Cormorants	2.28	2.36	2.46	2.56	2.66
Eider	2.29	2.37	2.47	2.57	2.67
King Eider		2.38	2.48	2.58	2.68
Velvet Scoter	2.30	2.39	2.49	2.59	2.69
Long-tailed Duck	2.31	2.40	2.50	2.60	2.70
Red-br. Merganser	2.32	2.41	2.51	2.61	2.71
Auks		2.42	2.52	2.62	2.72
Black Guillemot	2.33	2.43	2.53	2.63	2.73

Fig. 2. 1 Distribution of breeding Shags Phalacrocorax aristotelis in Møre og Romsdal. Scale refers to circle diameter and represents no. of individuals.

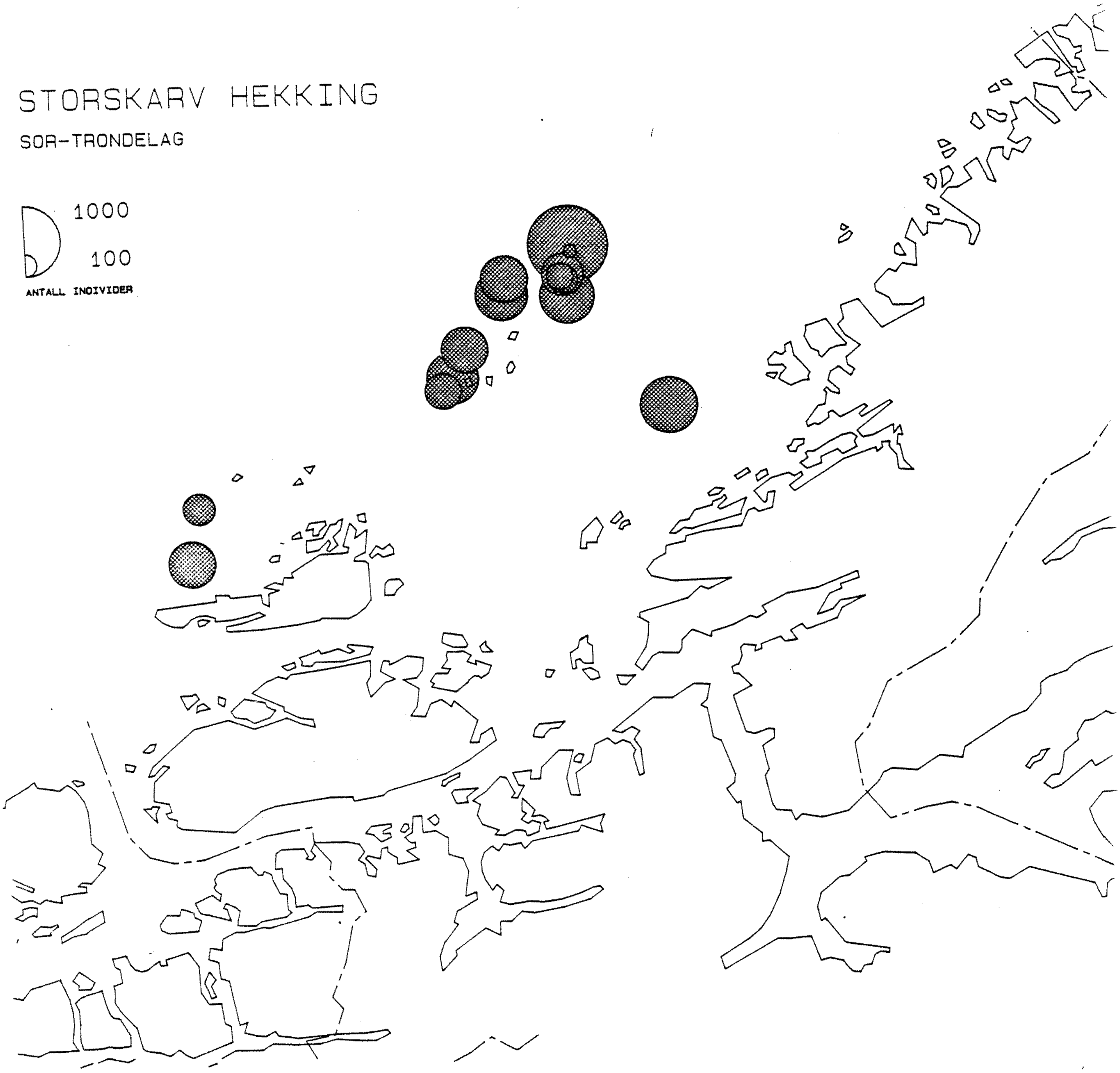


Fig. 2. 2 Distribution of breeding Cormorants <u>Phalacrocorax carbo</u> in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

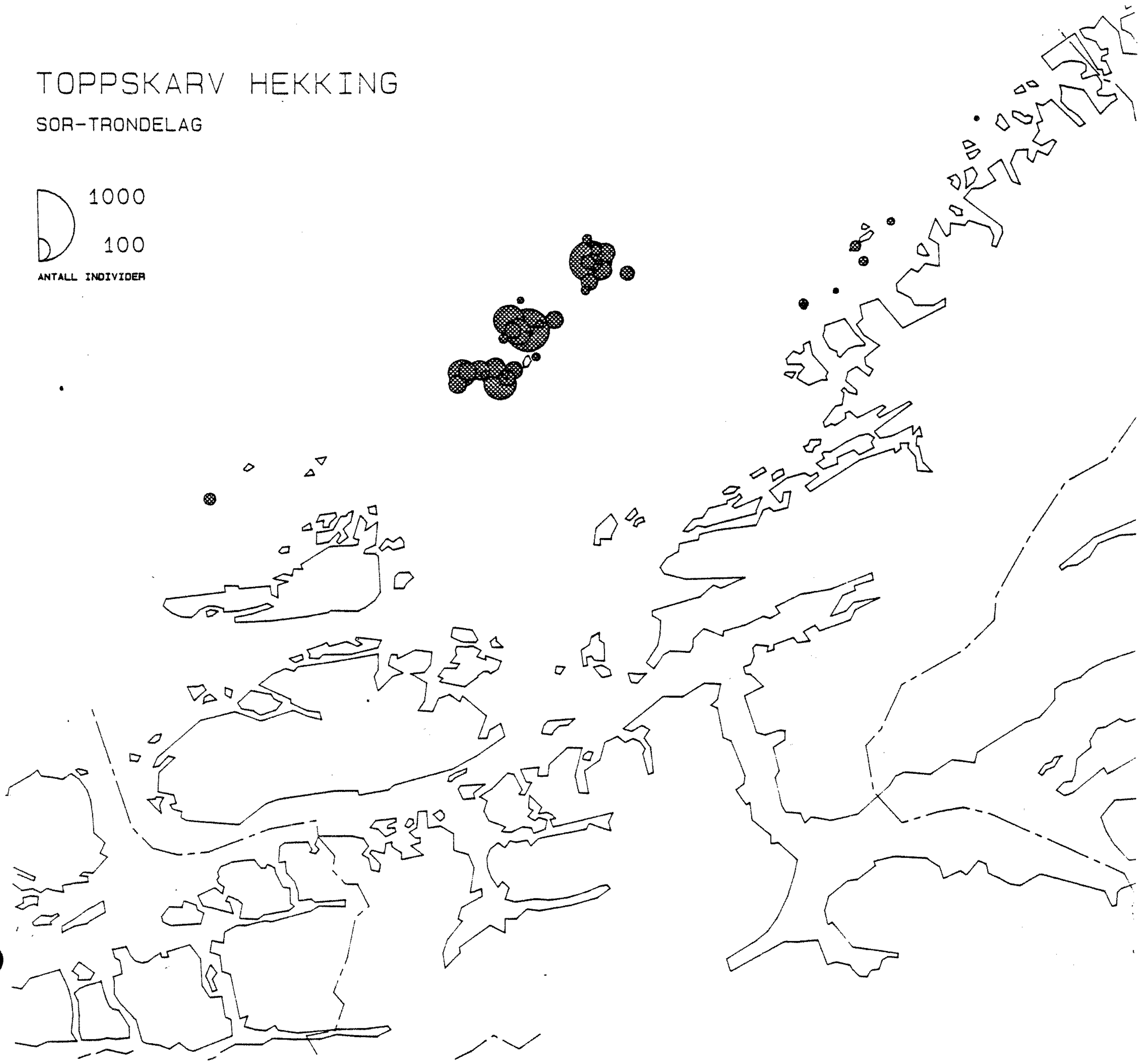


Fig. 2. 3 Distribution of breeding Shags Phalacrocorax aristotelis in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

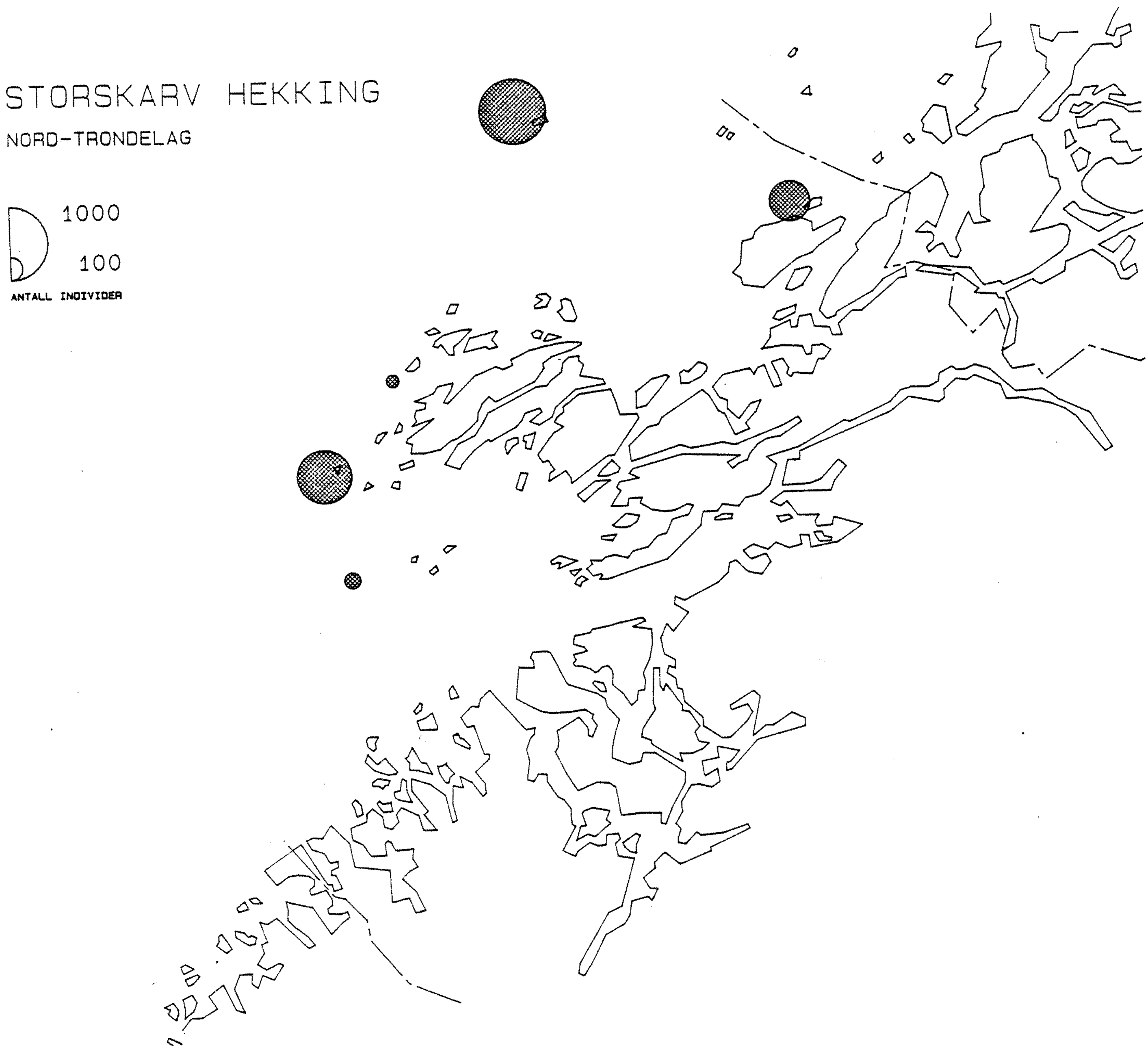


Fig. 2. 4 Distribution of breeding Cormorants <u>Phalacrocorax carbo</u> in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

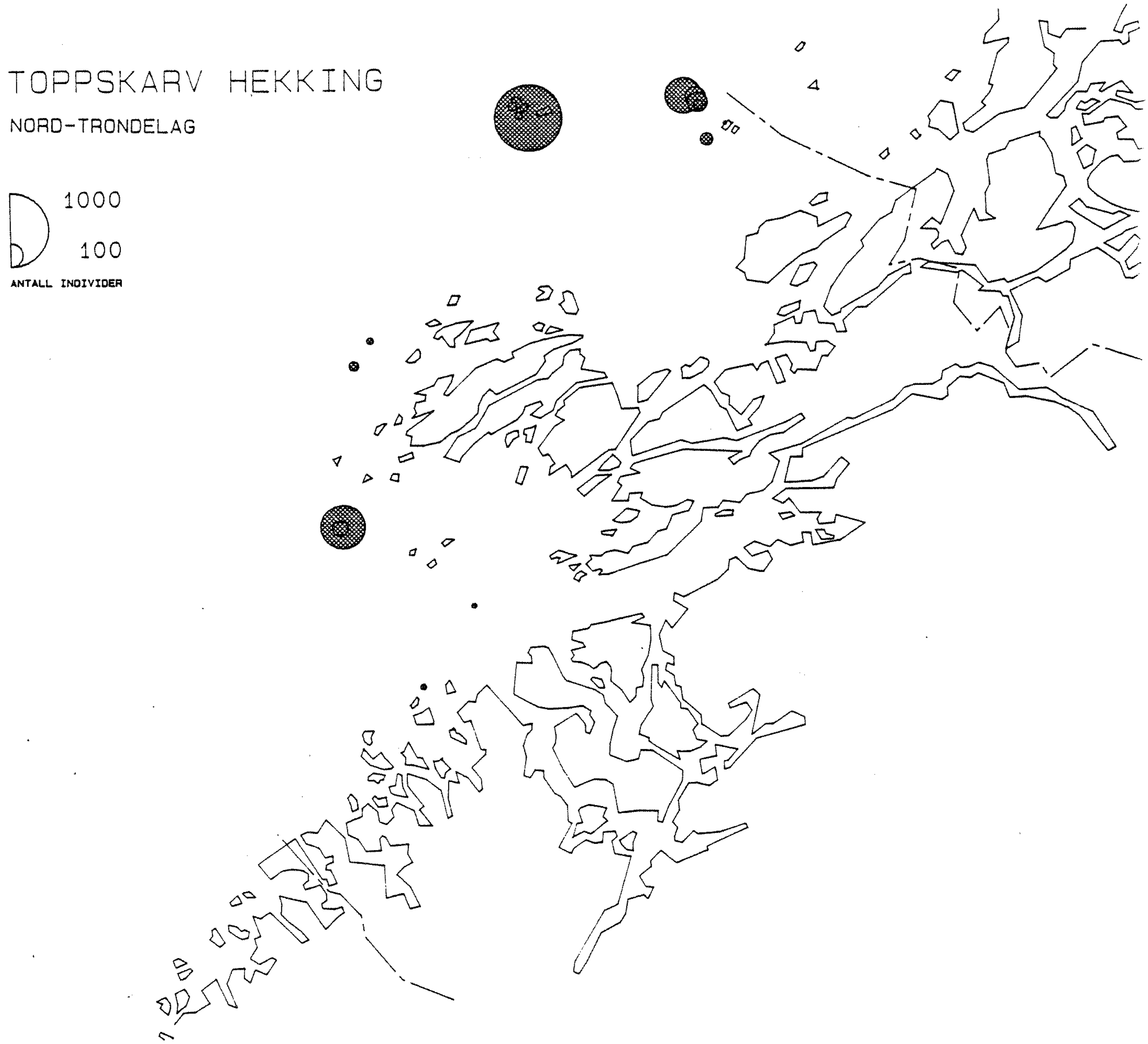


Fig. 2. 5 Distribution of breeding Shags *Phalacrocorax aristotelis* in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

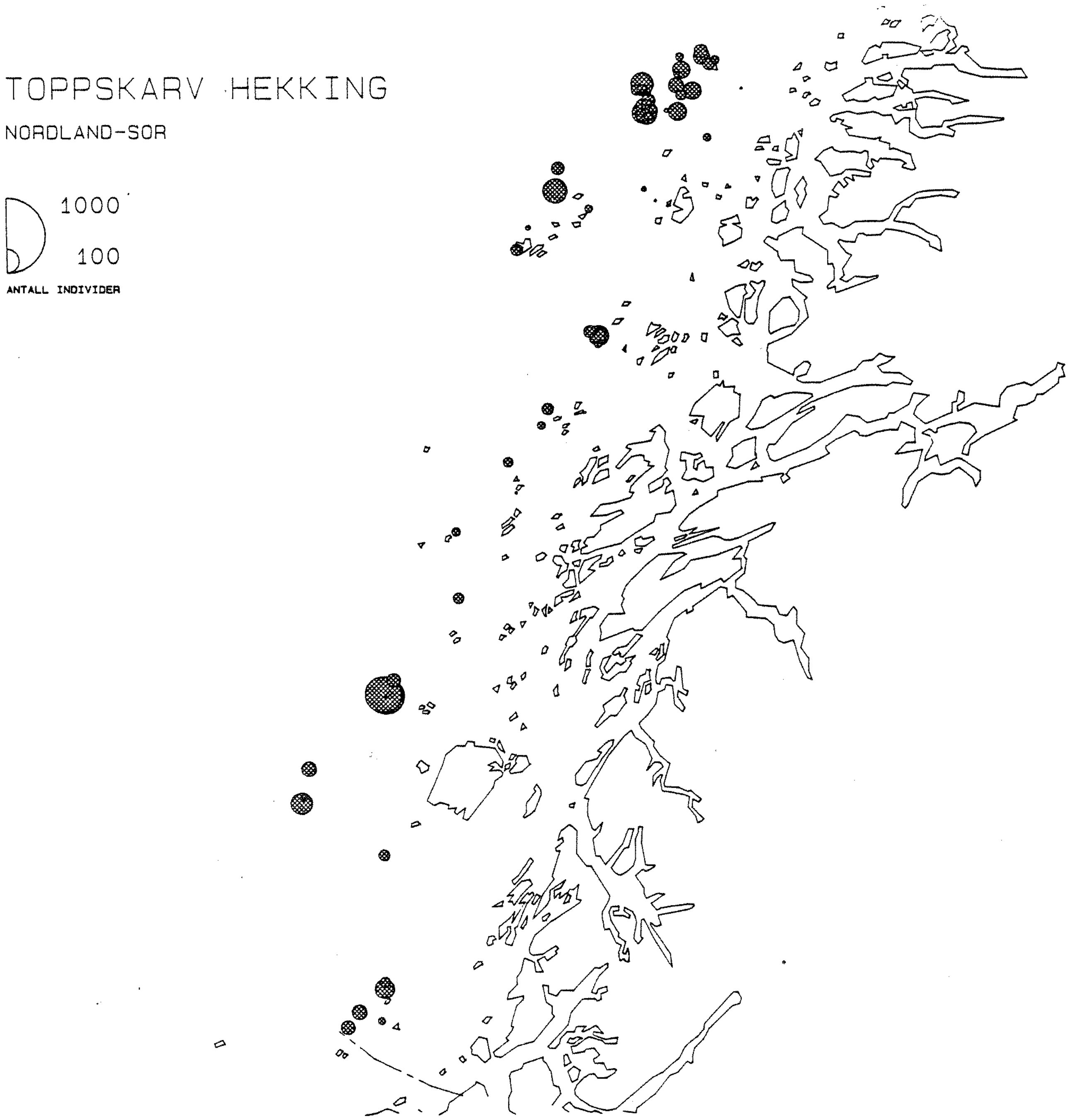


Fig. 2. 6 Distribution of breeding Shags Phalacrocorax aristotelis in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

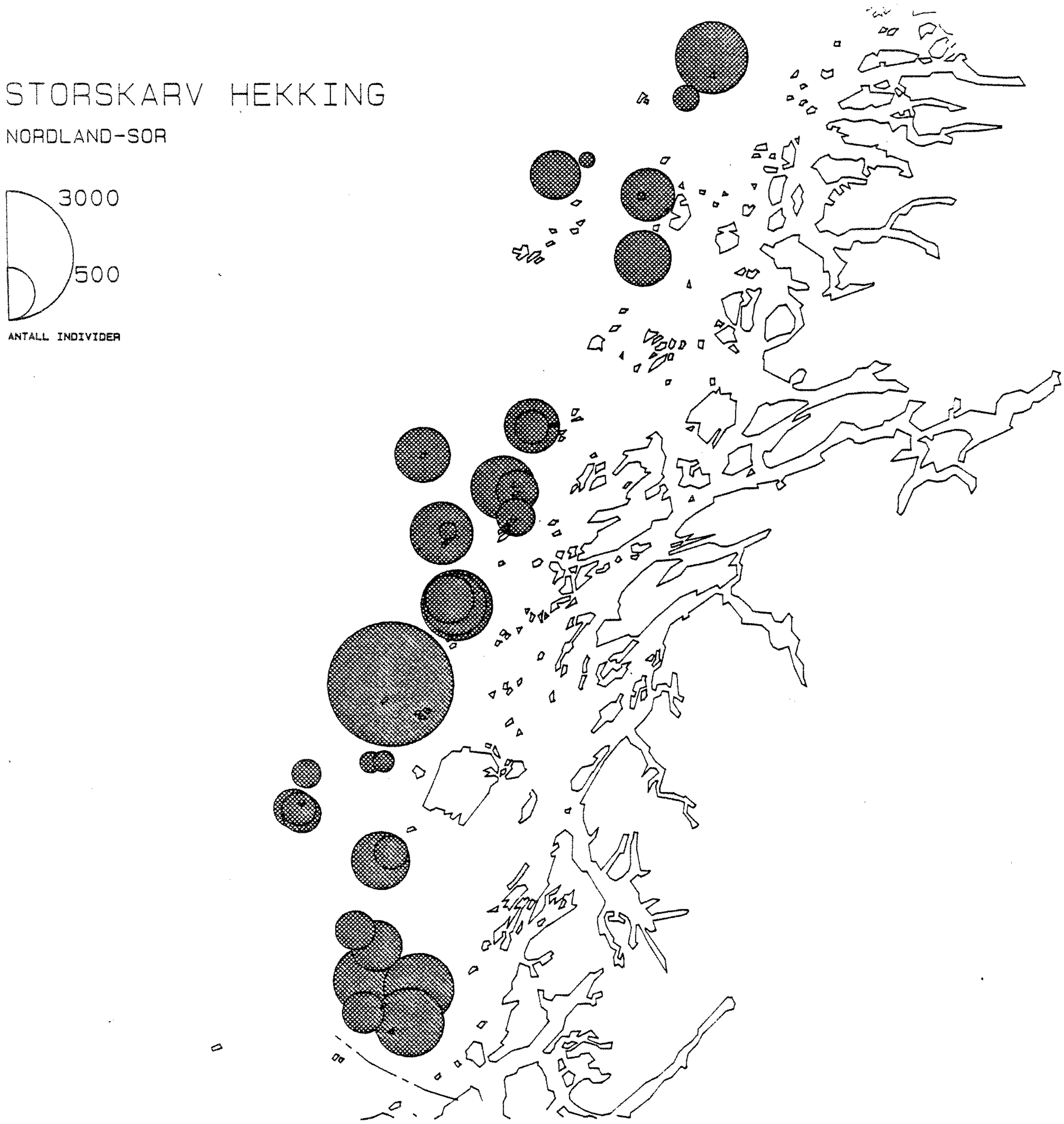


Fig. 2. 7 Distribution of breeding Cormorants *Phalacrocorax carbo* in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

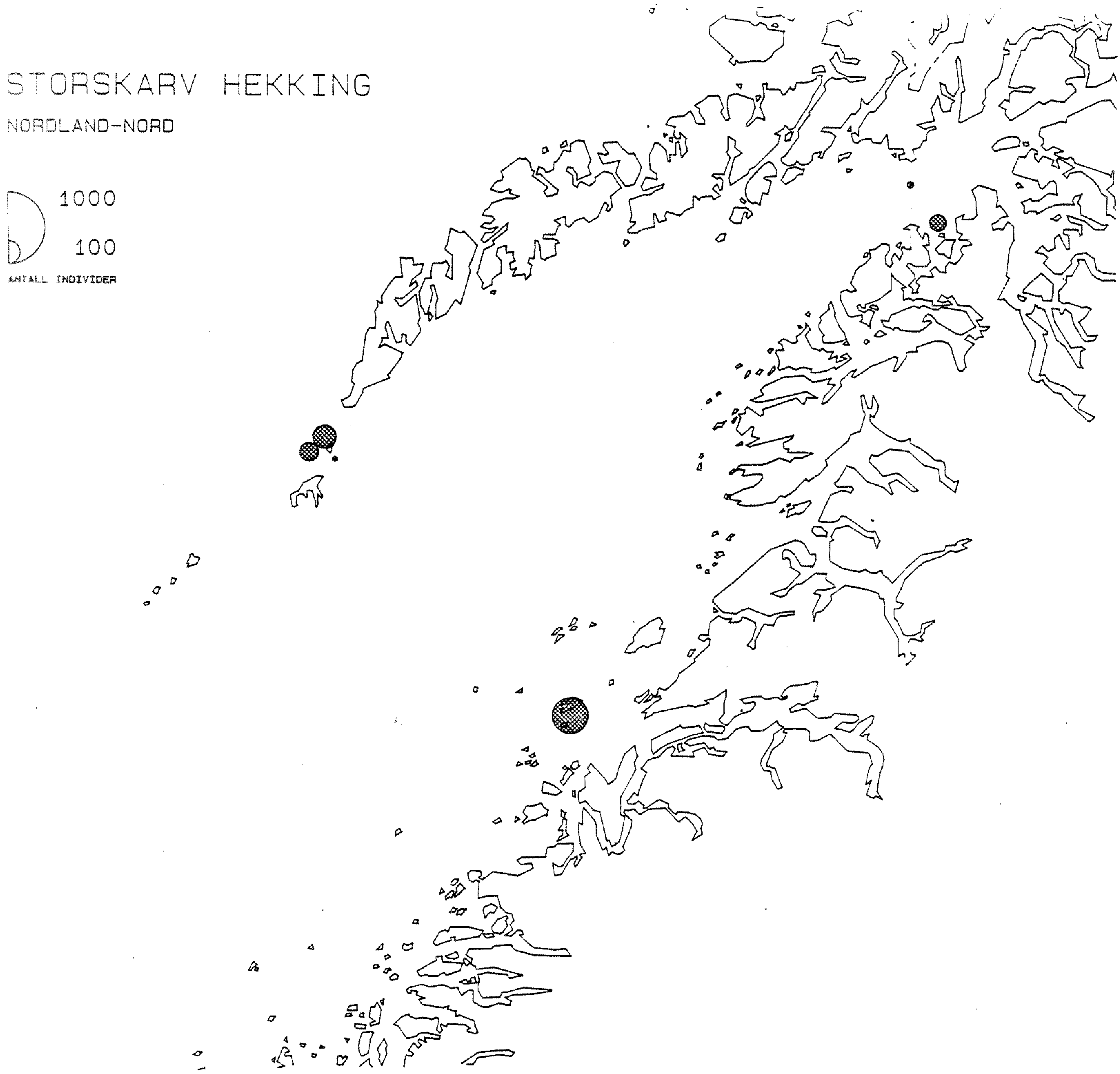


Fig. 2. 8 Distribution of breeding Cormorants <u>Phalacrocorax carbo</u> in Nordland (north). Scale refers to circle diameter and represents no. of individuals.

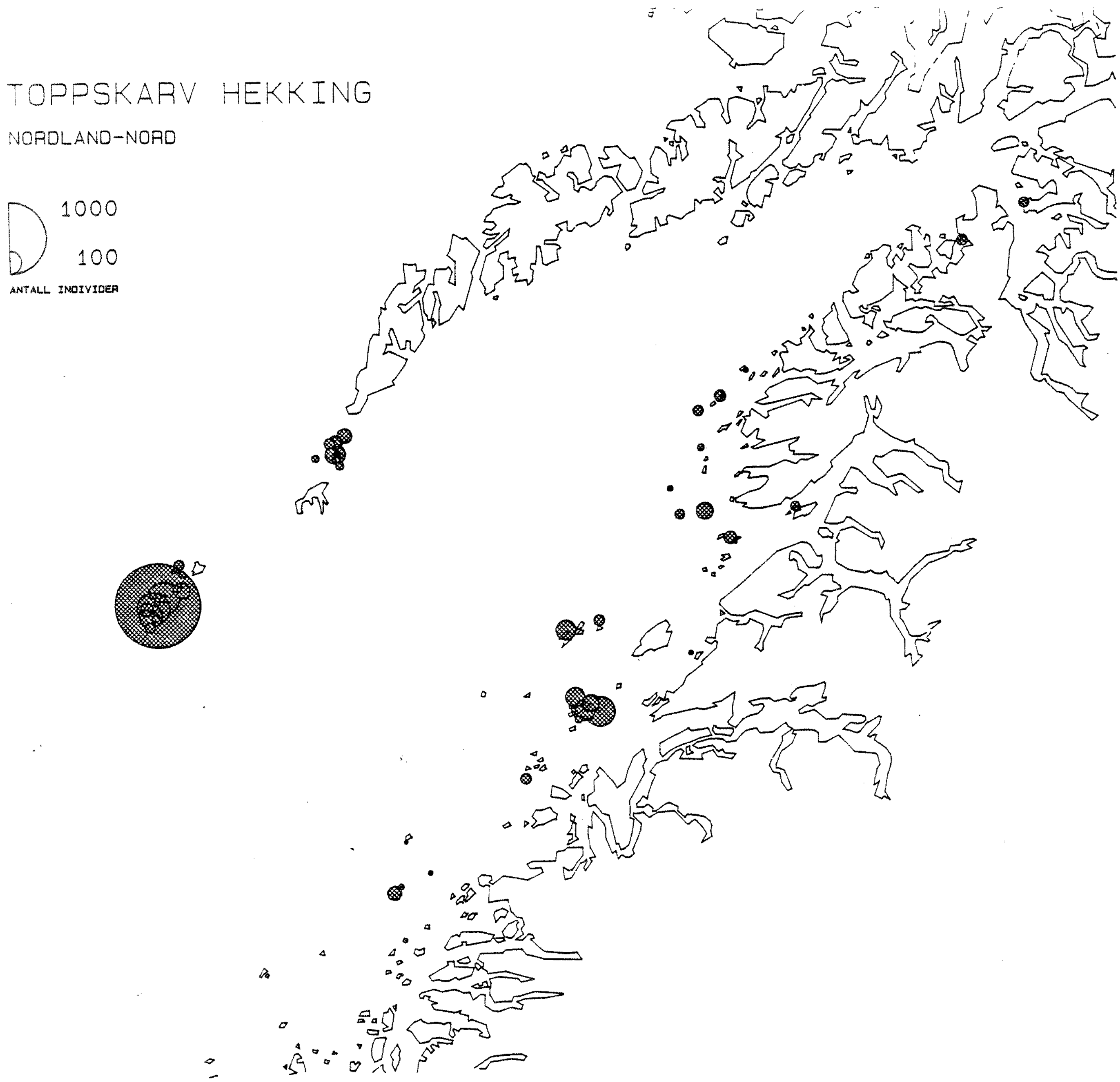


Fig. 2. 9 Distribution of breeding Shags <u>Phalacrocorax aristotelis</u> in Nordland (north). Scale refers to circle diameter and represents no. of individuals.

Fig. 2.10 Distribution of moulting Greylag Geese <u>Anser anser</u> in Møre og Romsdal. Scale refers to circle diameter and represents no. of individuals.

Fig. 2.11 Distribution of moulting Eiders Somateria mollissima in Møre og Romsdal. Scale refers to circle diameter and represents no. of individuals.

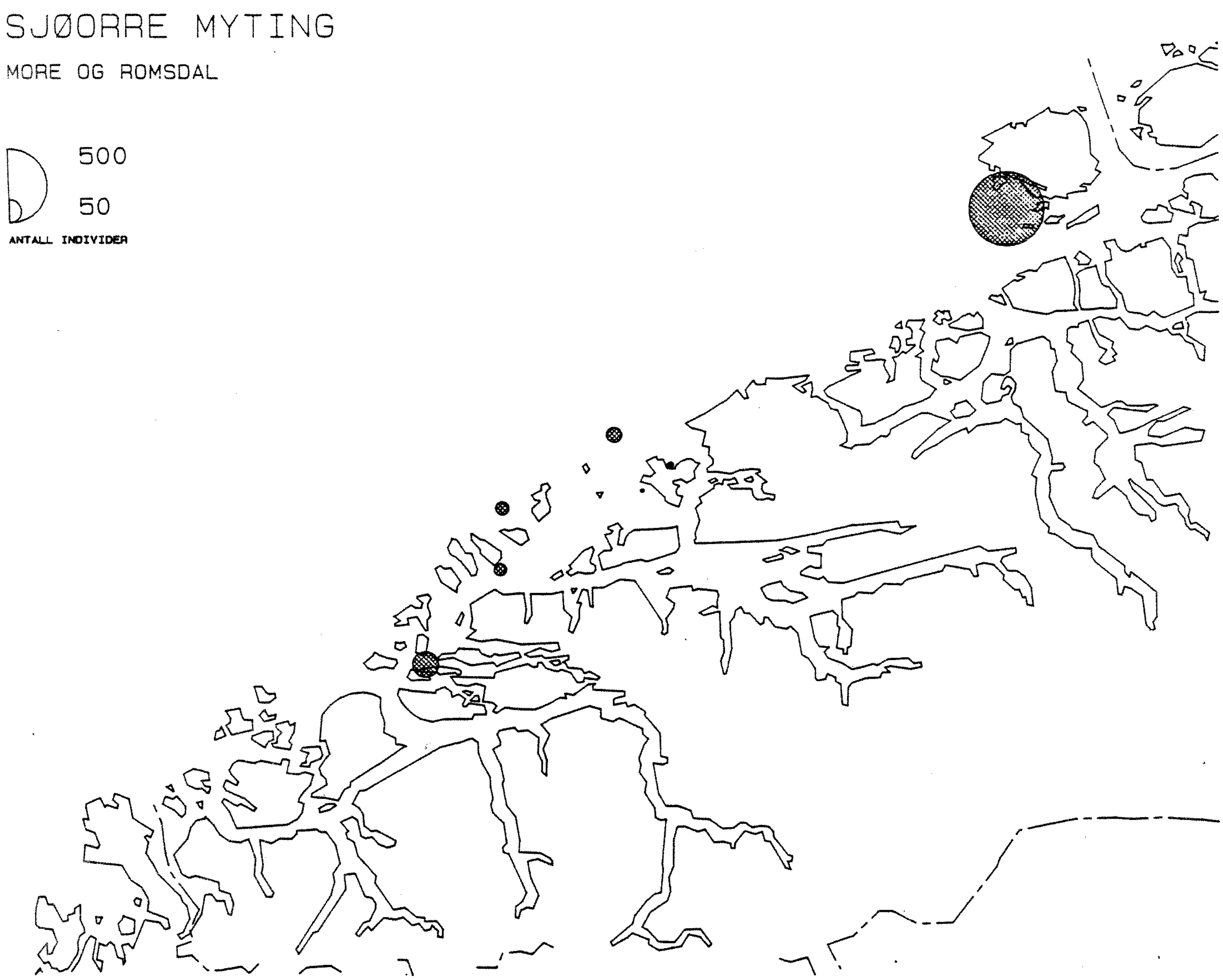


Fig. 2.12 Distribution of moulting Velvet Scoter *Melanitta fusca* in Møre og Romsdal. Scale refers to circle diameter and represents no. of individuals.

Fig. 2.13 Distribution of moulting Red-Breasted Merganser <u>Mergus serrator</u> in Møre og Romsdal. Scale refers to circle diameter and represents no. of individuals.

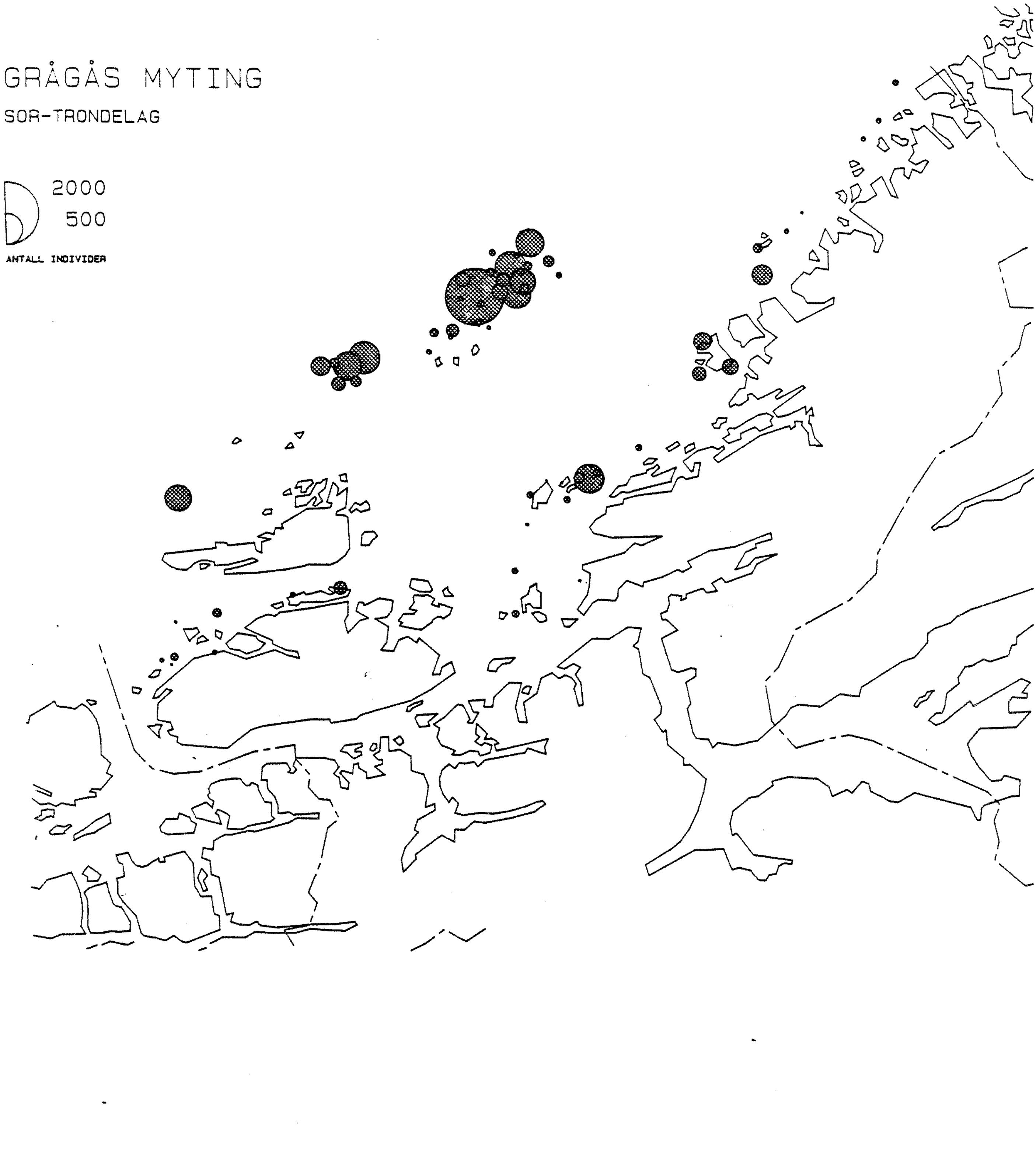


Fig. 2.14 Distribution of moulting Greylag Geese <u>Anser anser</u> in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

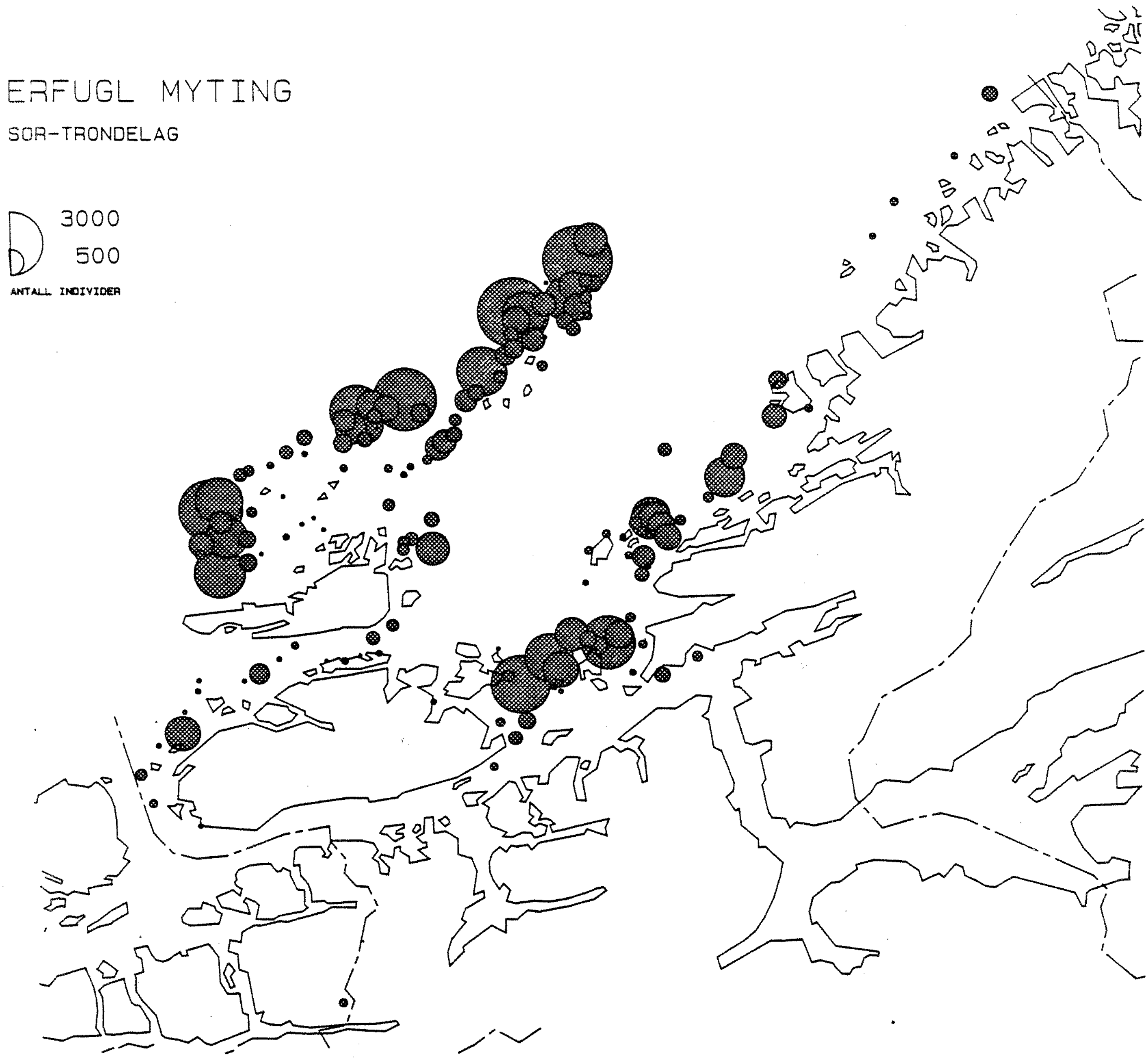


Fig. 2.15 Distribution of moulting Eiders Somateria mollissima in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

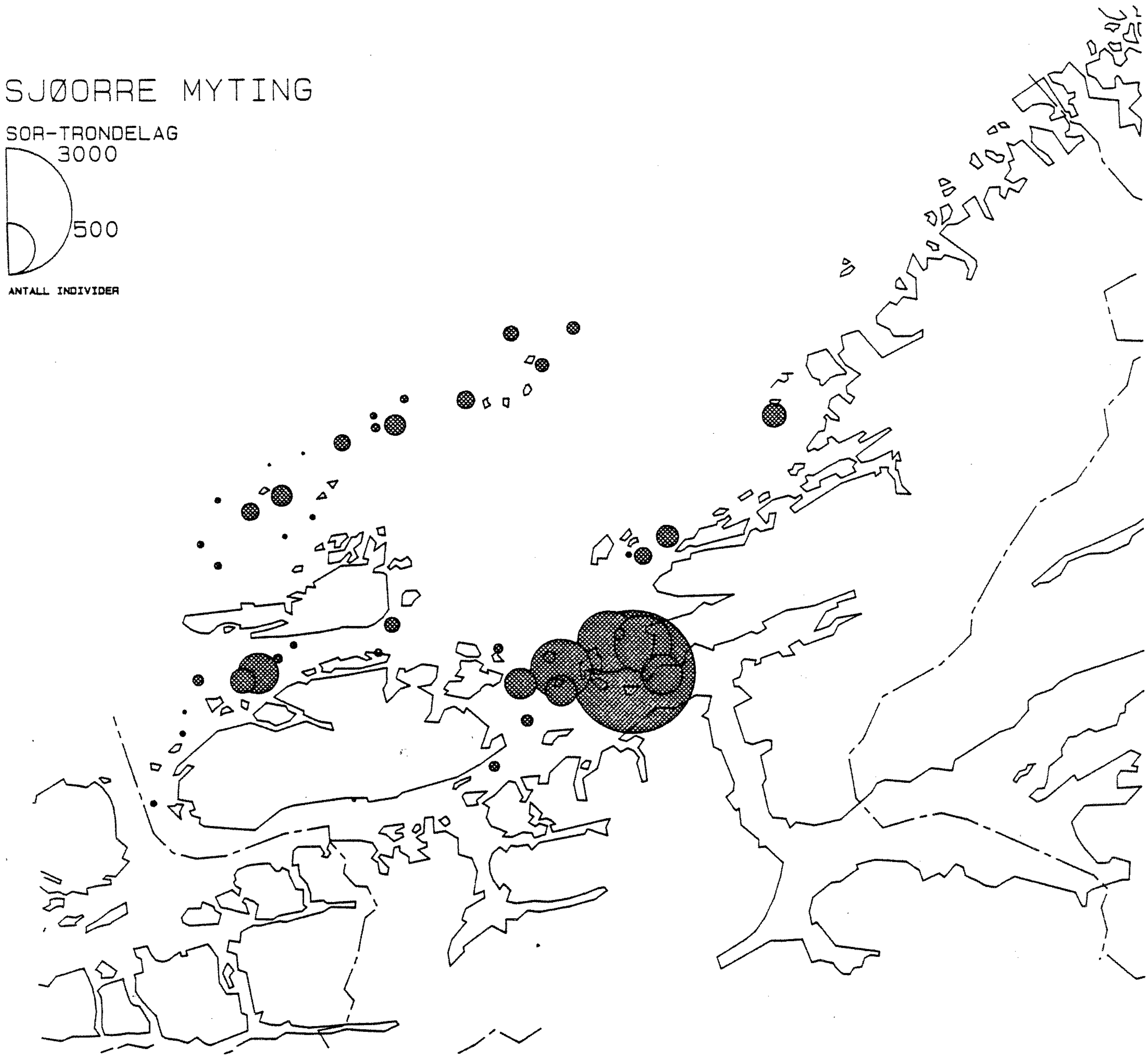


Fig. 2.16 Distribution of moulting Velvet Scoter *Melanitta fusca* in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

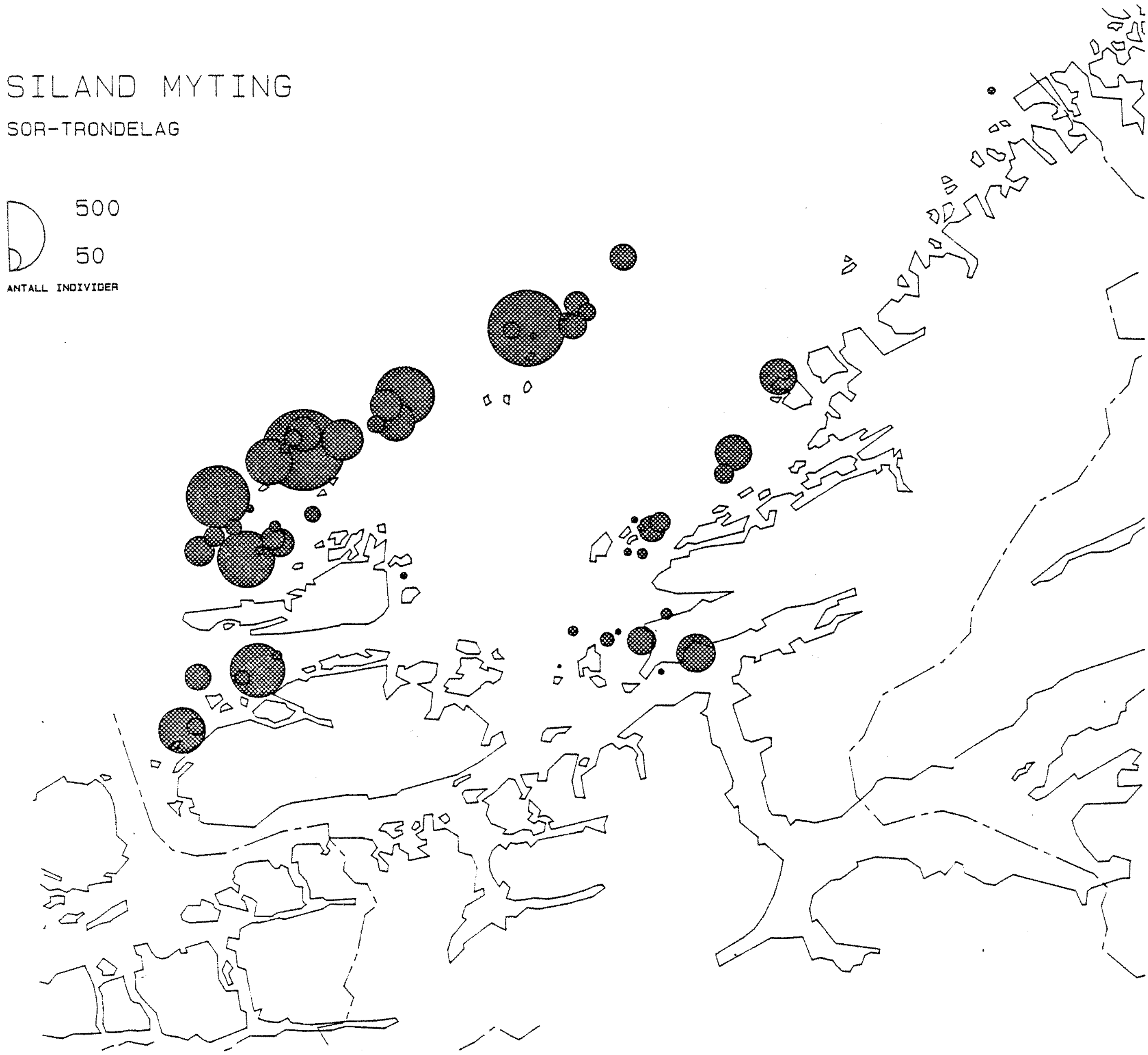


Fig. 2.17 Distribution of moulting Red-Breasted Merganser *Mergus serrator* in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

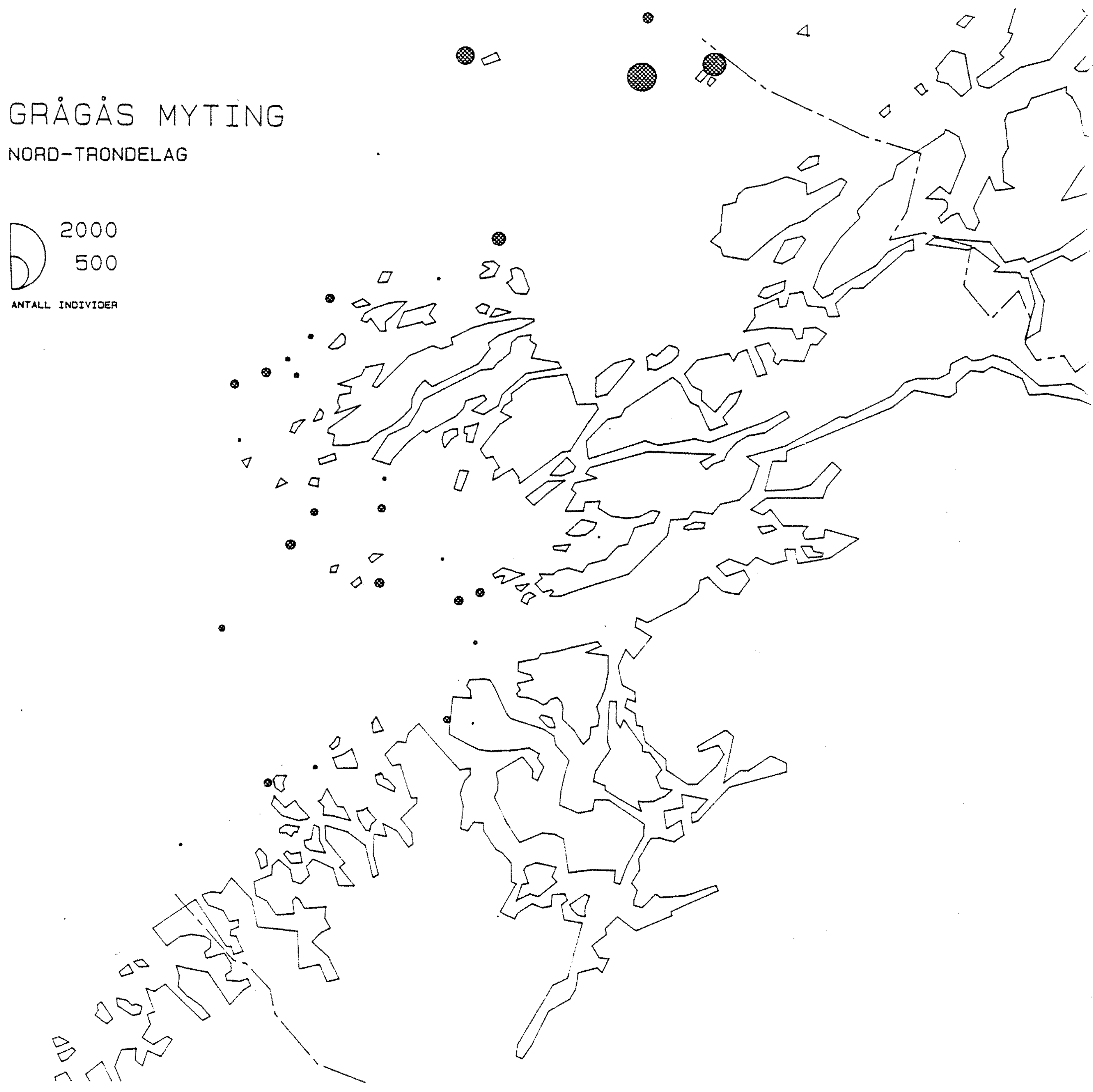


Fig. 2.18 Distribution of moulting Greylag Geese <u>Anser anser</u> in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

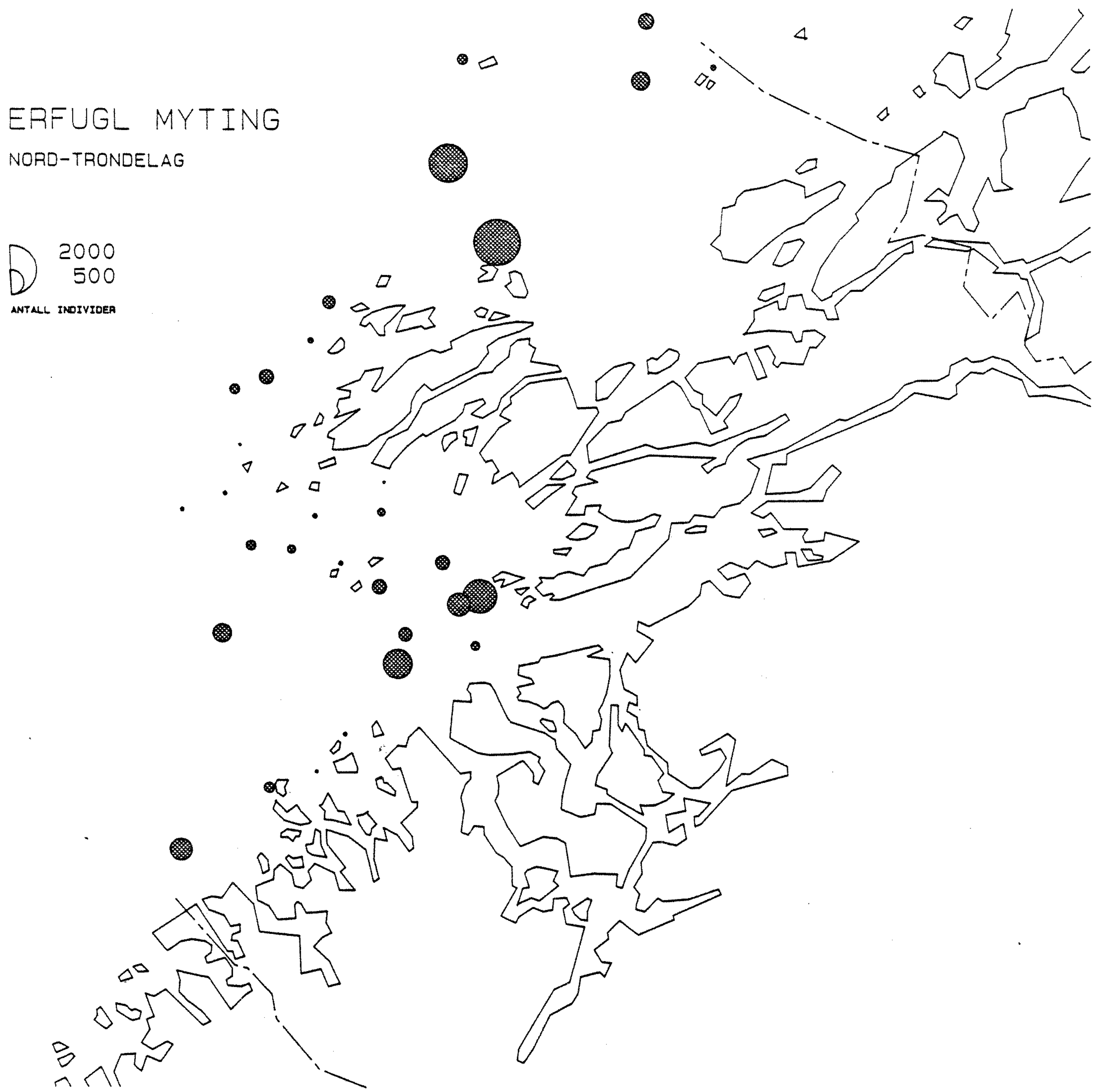


Fig. 2.19 Distribution of moulting Eiders Somateria mollissima in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

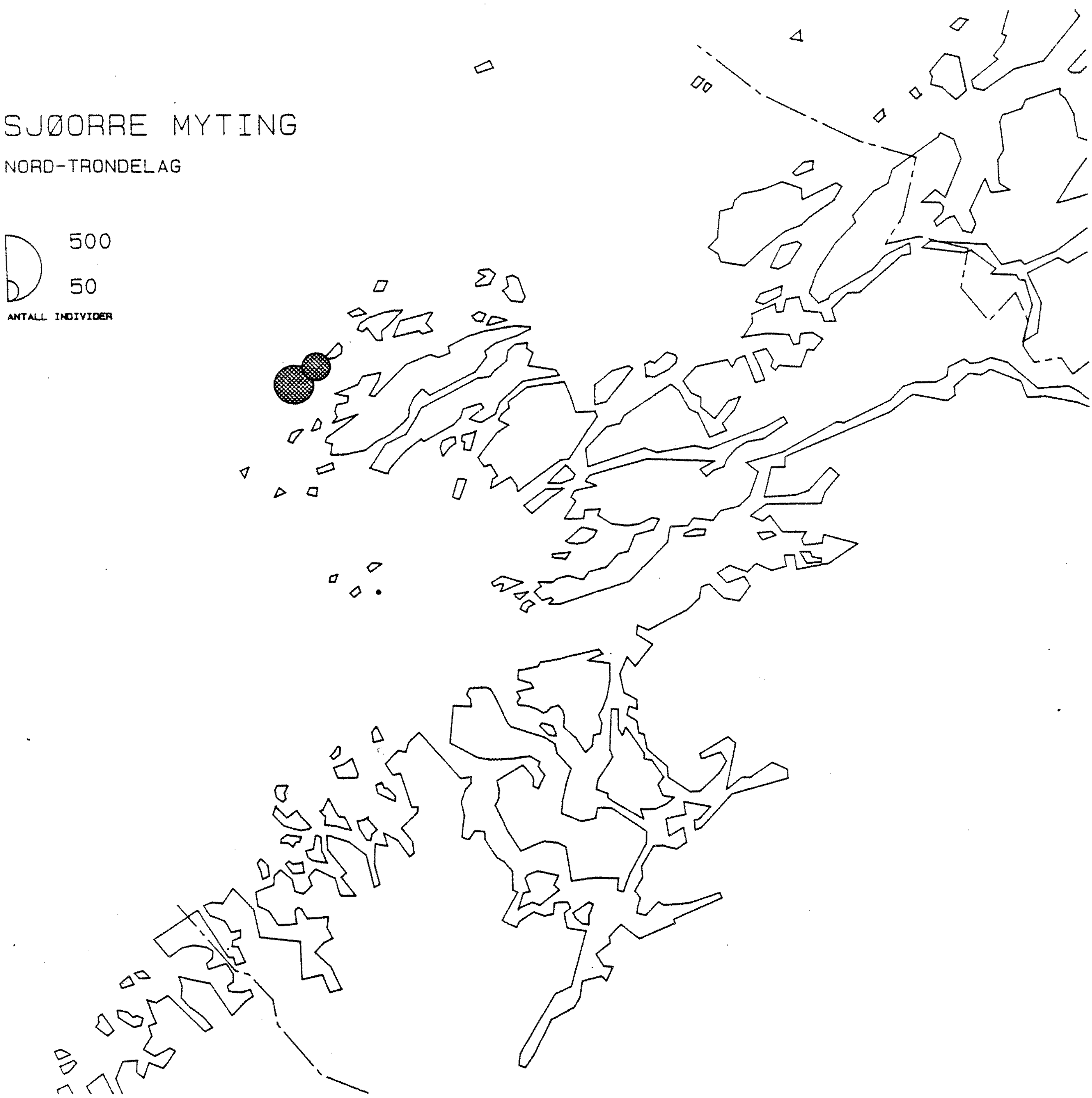


Fig. 2.20 Distribution of moulting Velvet Scoter _Melanitta fusca_ in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

Fig. 2.21. Distribution of moulting Red-Breasted Merganser *Mergus serrator* in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

Fig. 2.22 Distribution of moulting Greylag Geese *Anser anser* in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

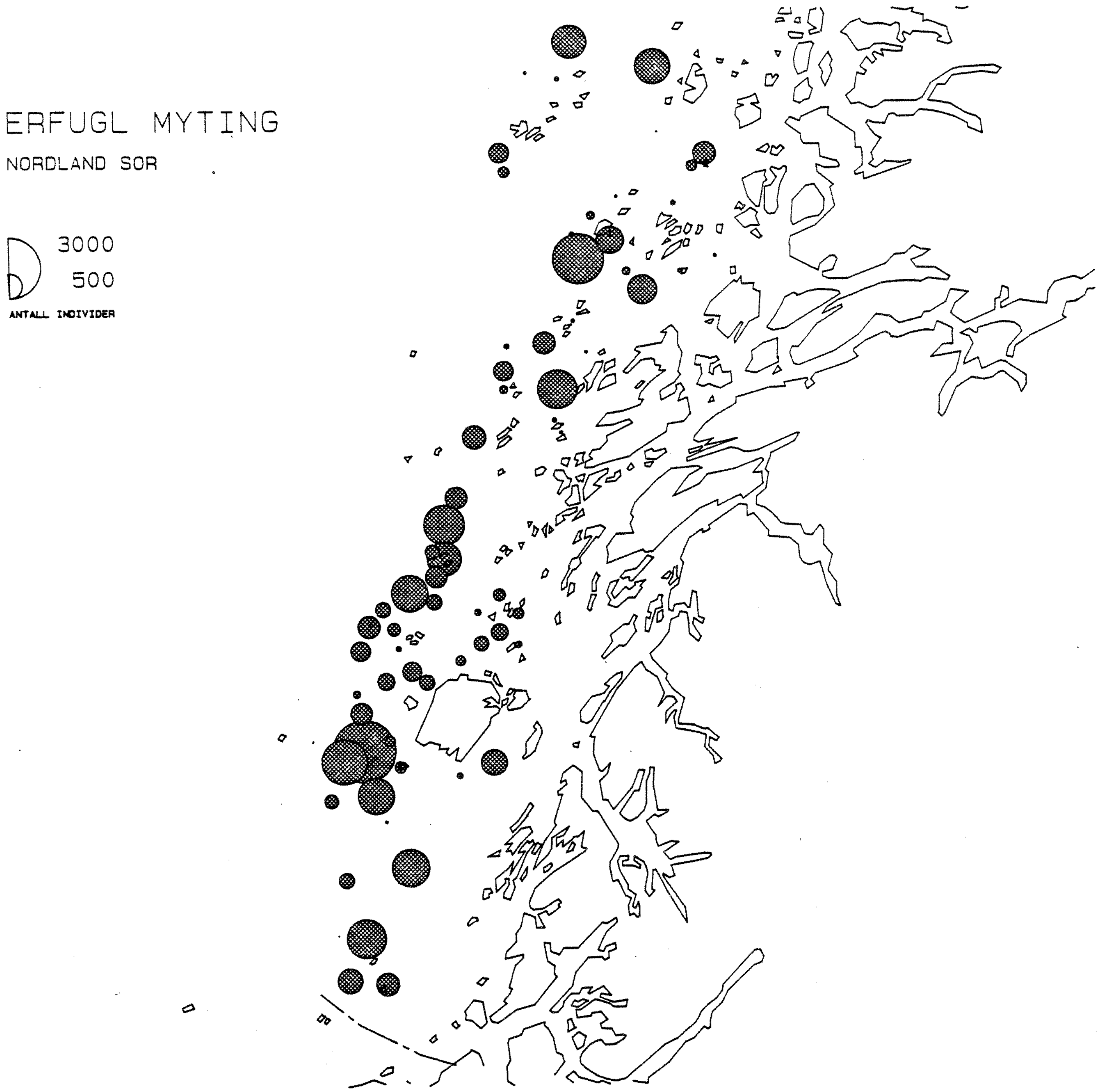


Fig. 2.23 Distribution of moulting Eiders *Somateria mollissima* in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

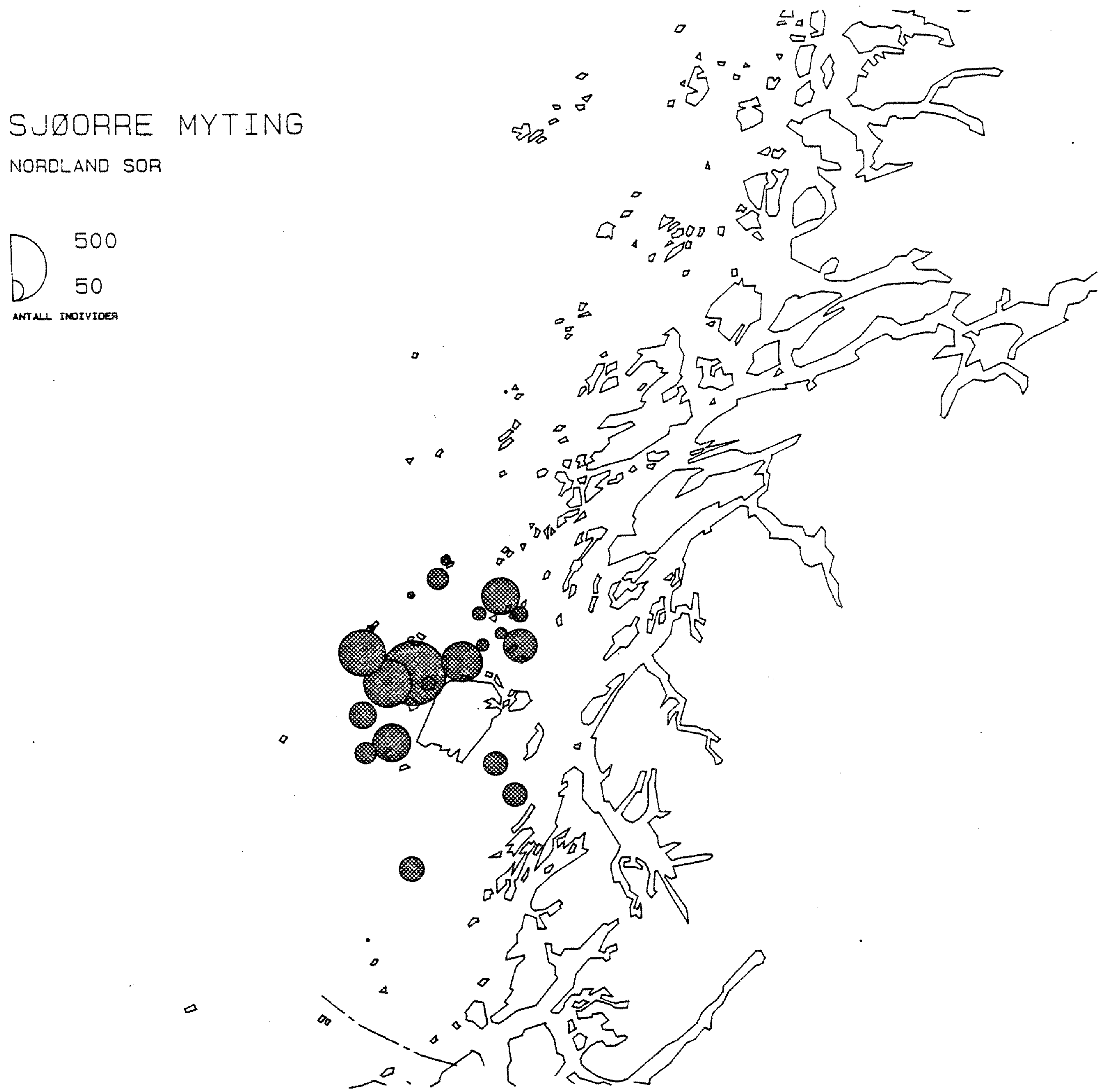


Fig. 2.24. Distribution of moulting Velvet Scoter <u>Melanitta fusca</u> in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

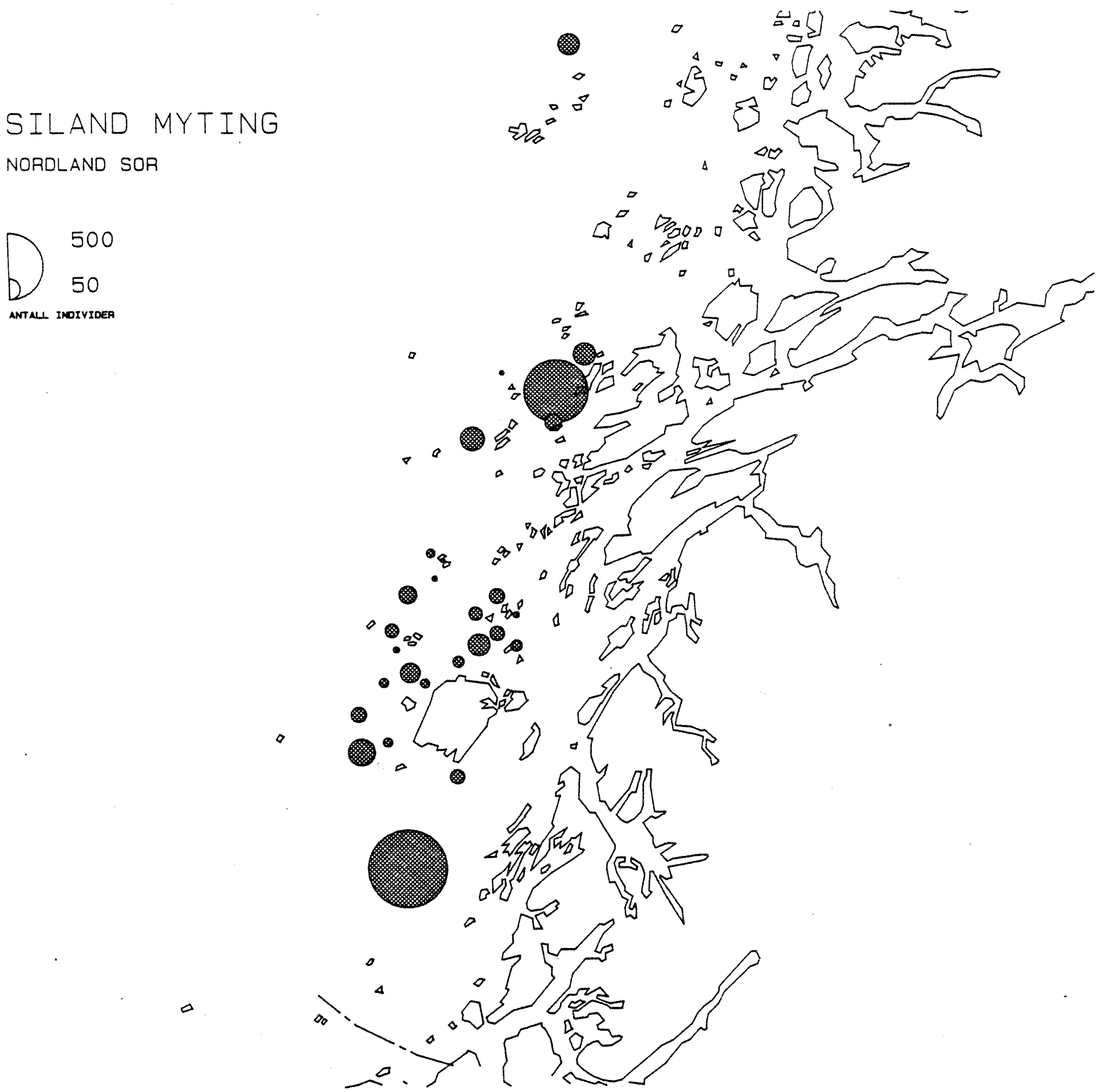


Fig. 2.25. Distribution of moulting Red-Breasted Merganser <u>Mergus serrator</u> in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

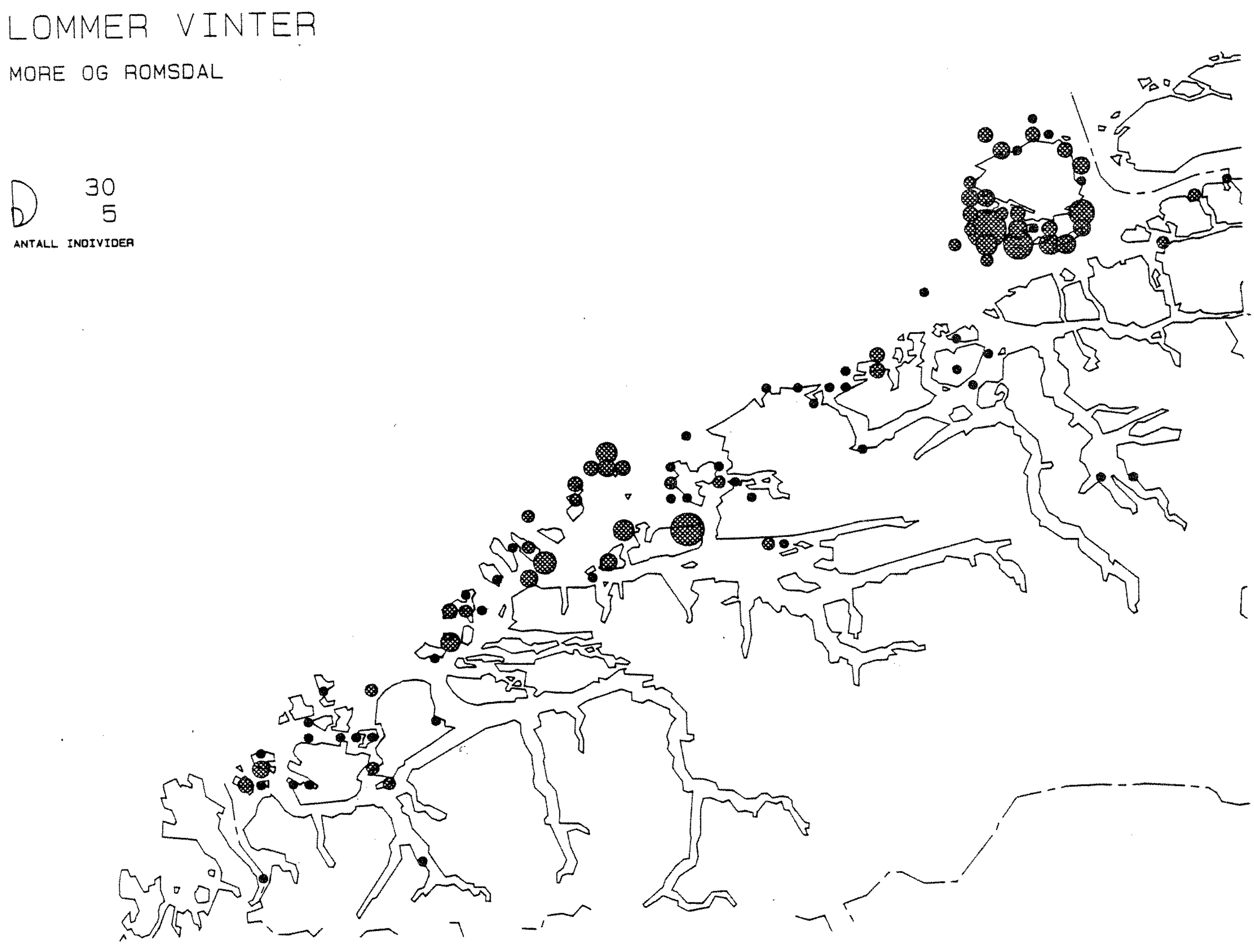


Fig. 2.26. Distribution of wintering Divers Gavia sp. in Møre og Romsdal. Scale refers to circle diameter and represents no. of individuals.

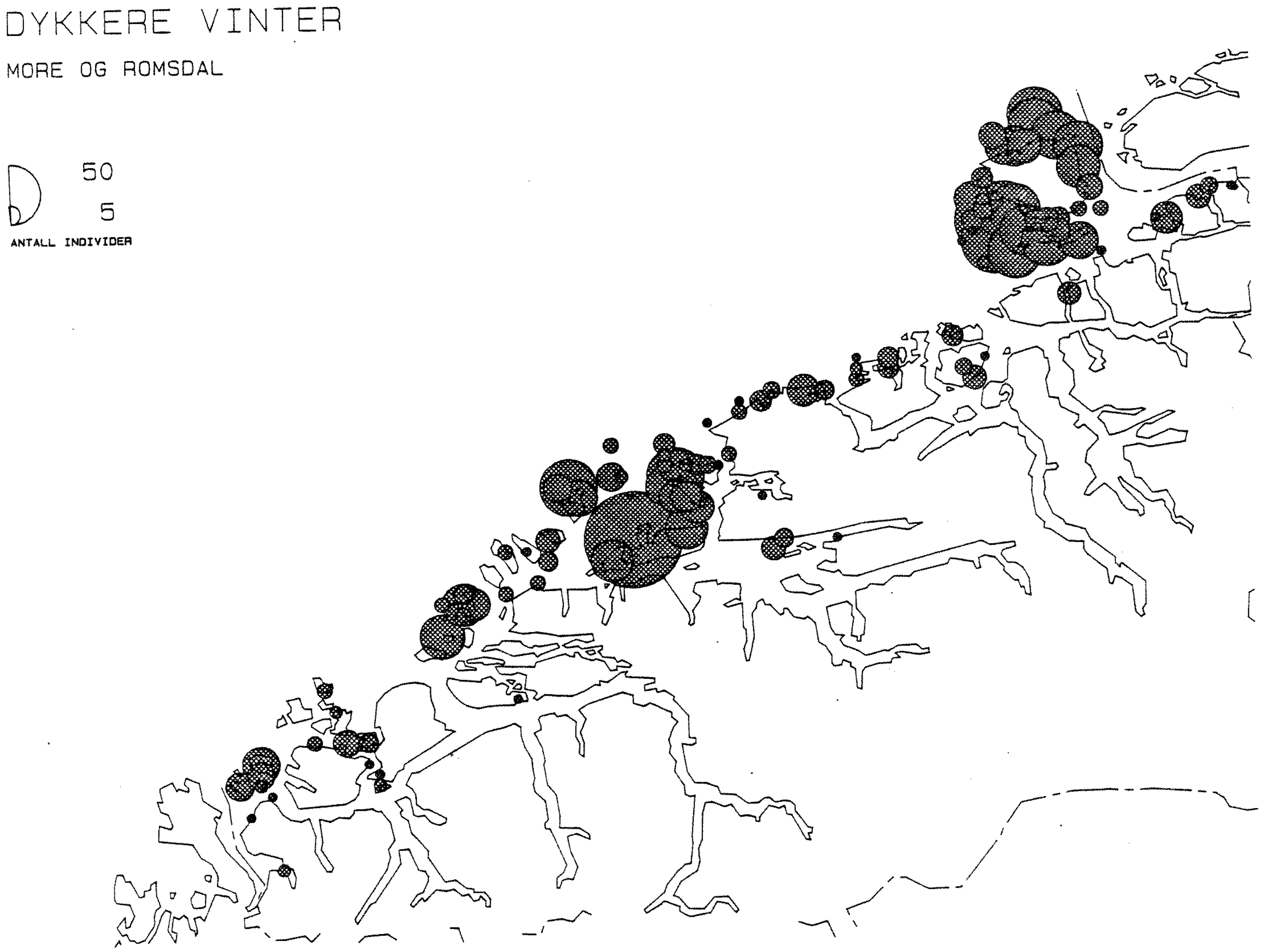


Fig. 2.27 . Distribution of wintering Grebes <u>Podiceps sp.</u> in Møre og Romsdal. Scale refers to circle diameter and represents no. of individuals.

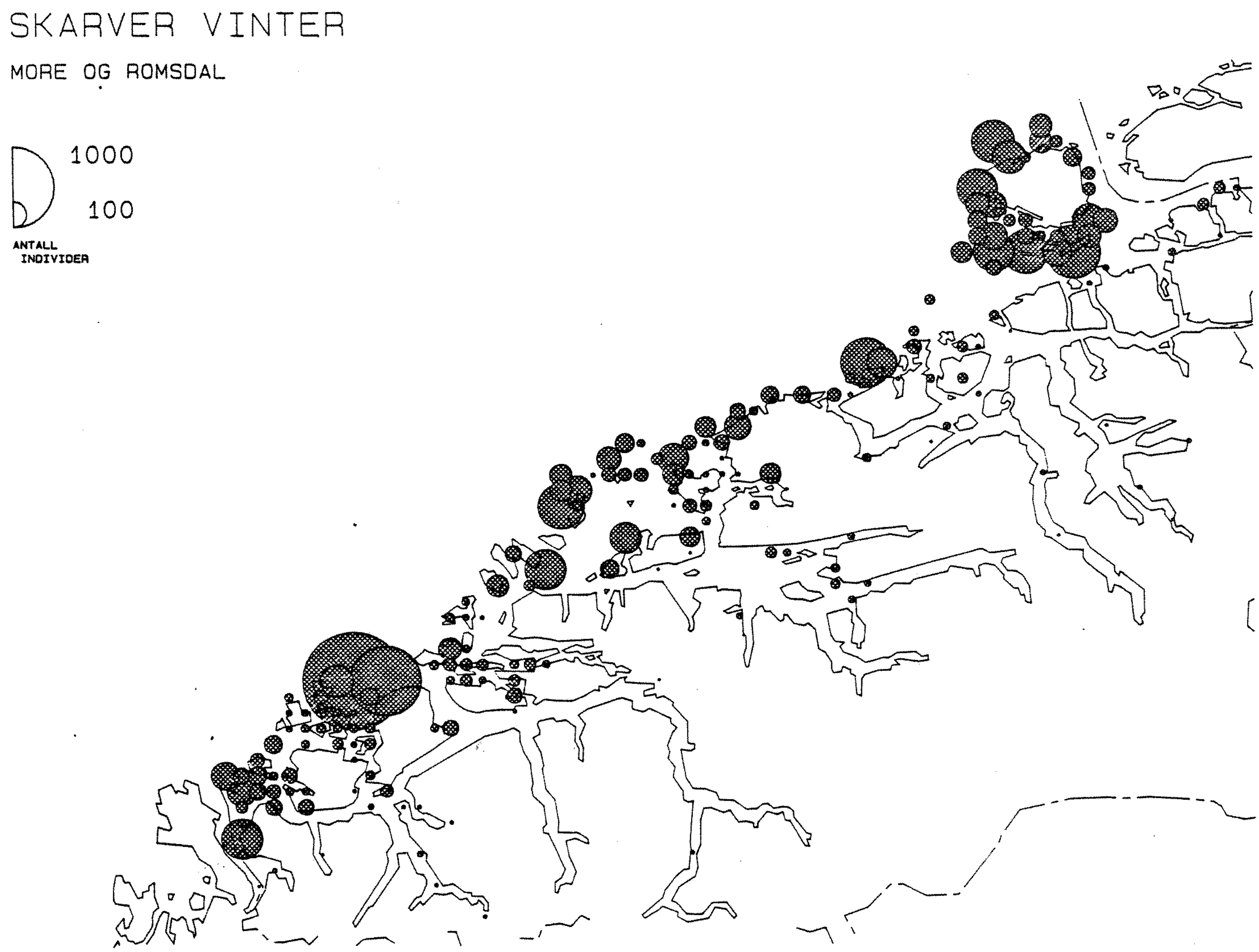


Fig. 2.28. Distribution of wintering Shags <u>Phalacrocorax sp.</u> in Møre og Romsdal. Scale refers to circle diameter and represents no. of individuals.

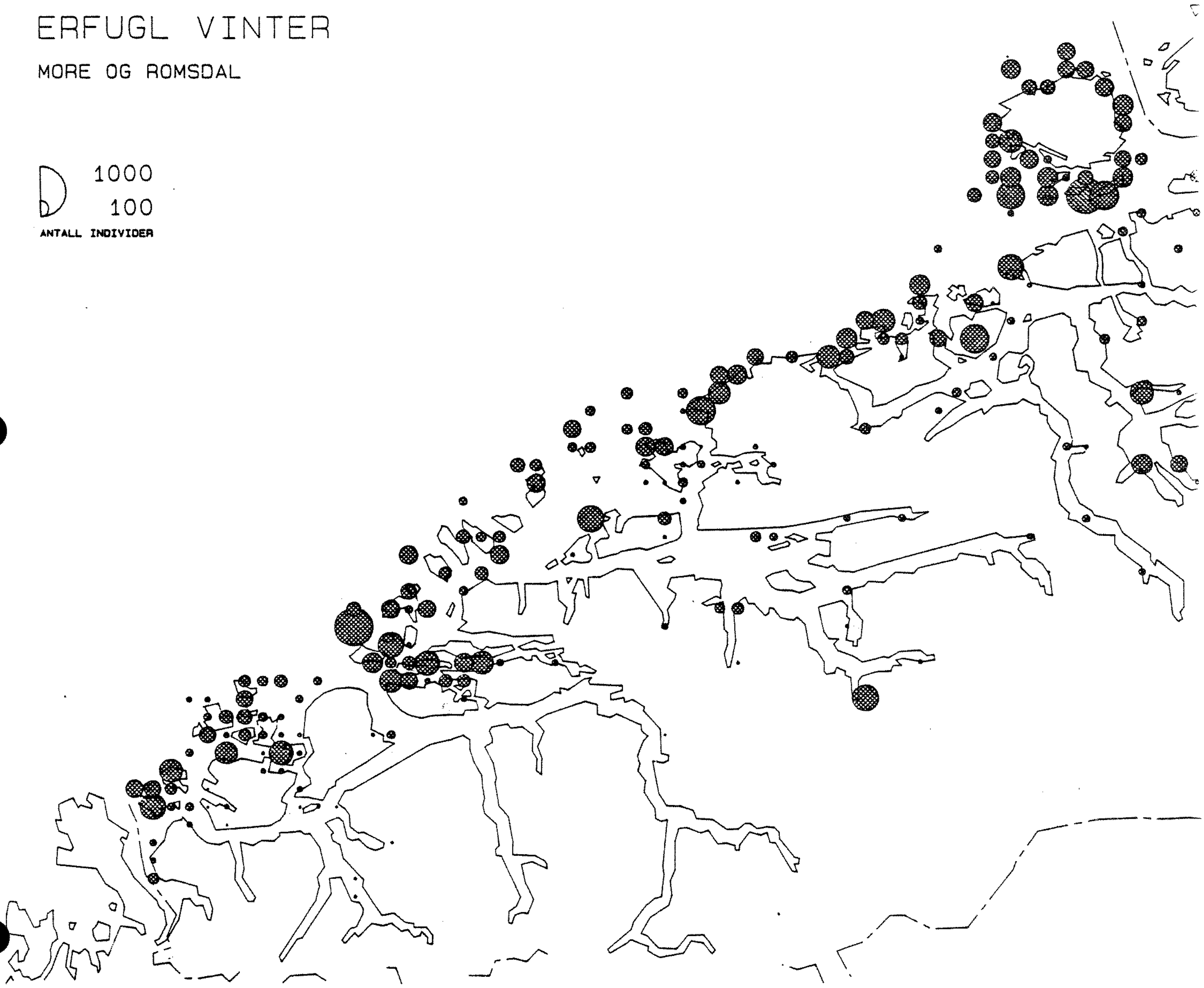


Fig. 2.29 Distribution of wintering Eiders <u>Somateria mollissima</u> in Møre og Romsdal. Scale refers to circle diameter and represents no. of individuals.

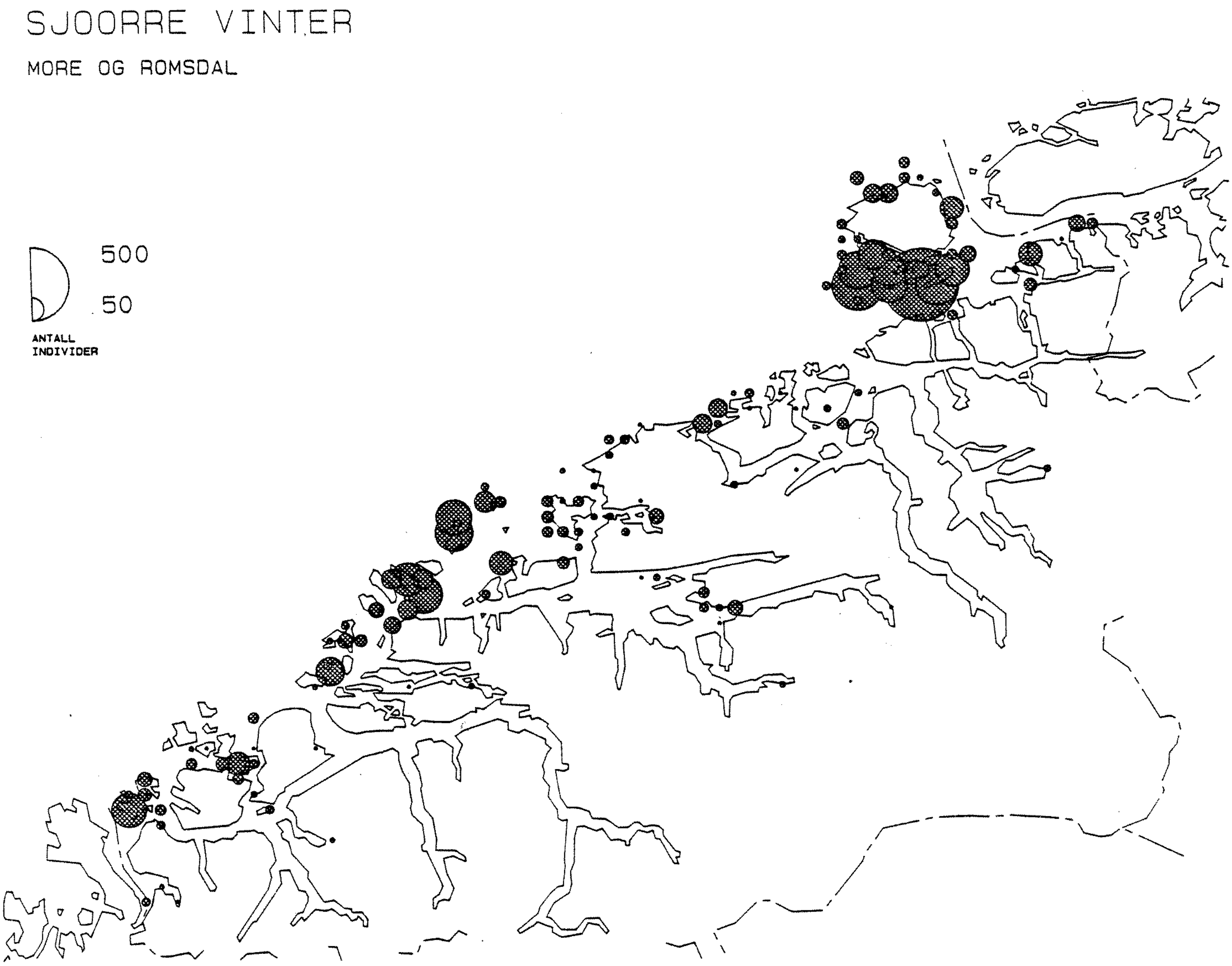


Fig. 2.30. Distribution of wintering Velvet Scoters <u>Melanitta fusca</u> in Møre og Romsdal. Scale refers to circle diameter and represents no. of individuals.

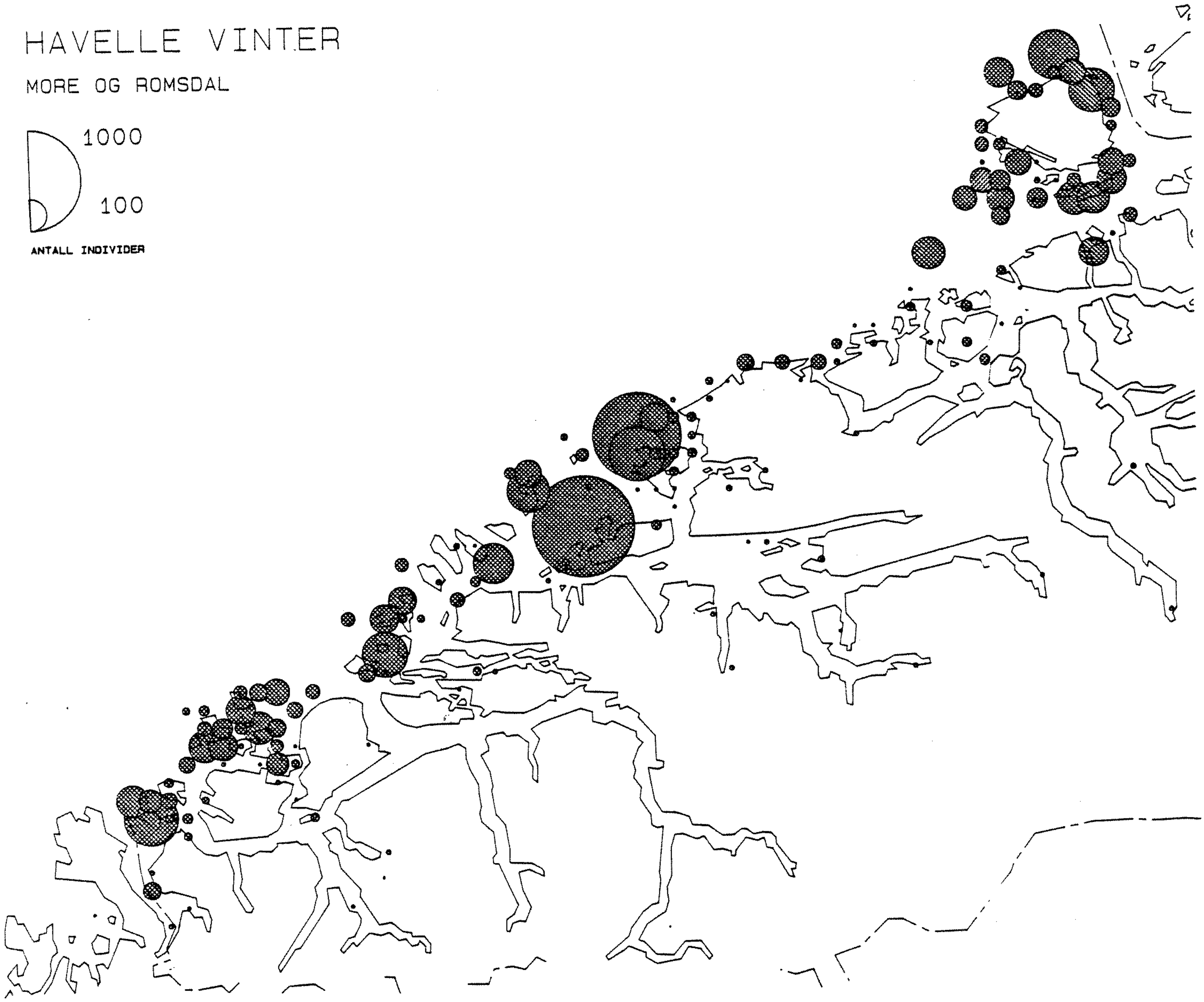


Fig. 2.31. Distribution of wintering Long-tailed Ducks <u>Clangula hyemalis</u> in Møre og Romsdal. Scale refers to circle diameter and represents no. of individuals.

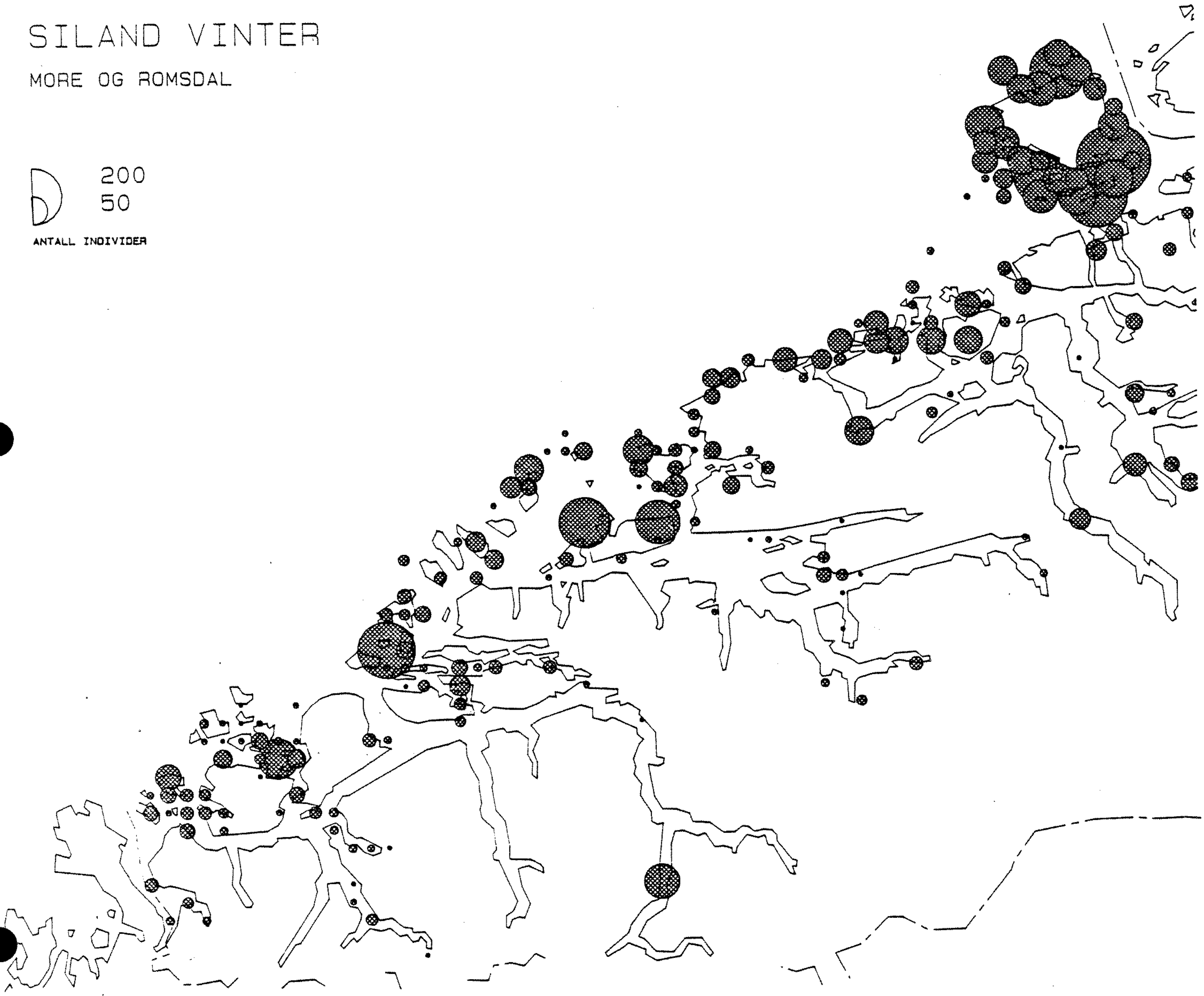


Fig. 2.32 . Distribution of wintering Red-breasted Mergansers <u>Mergus serrator</u> in Møre og Romsdal. Scale refers to circle diameter and represents no. of individuals.

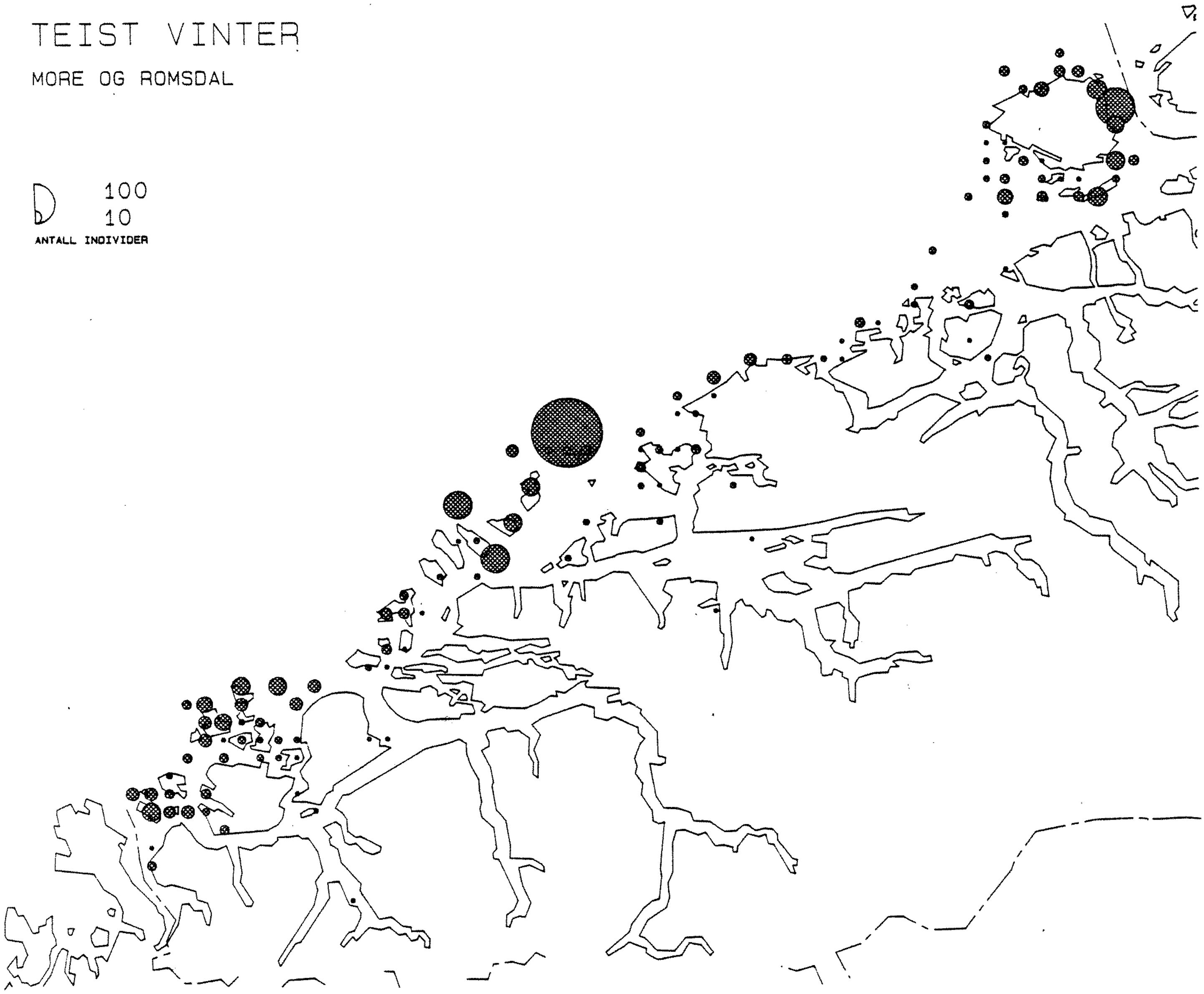


Fig. 2.33 . Distribution of wintering Black Guillemots <u>Cepphus grylle</u> in Møre og Romsdal. Scale refers to circle diameter and represents no. of individuals.

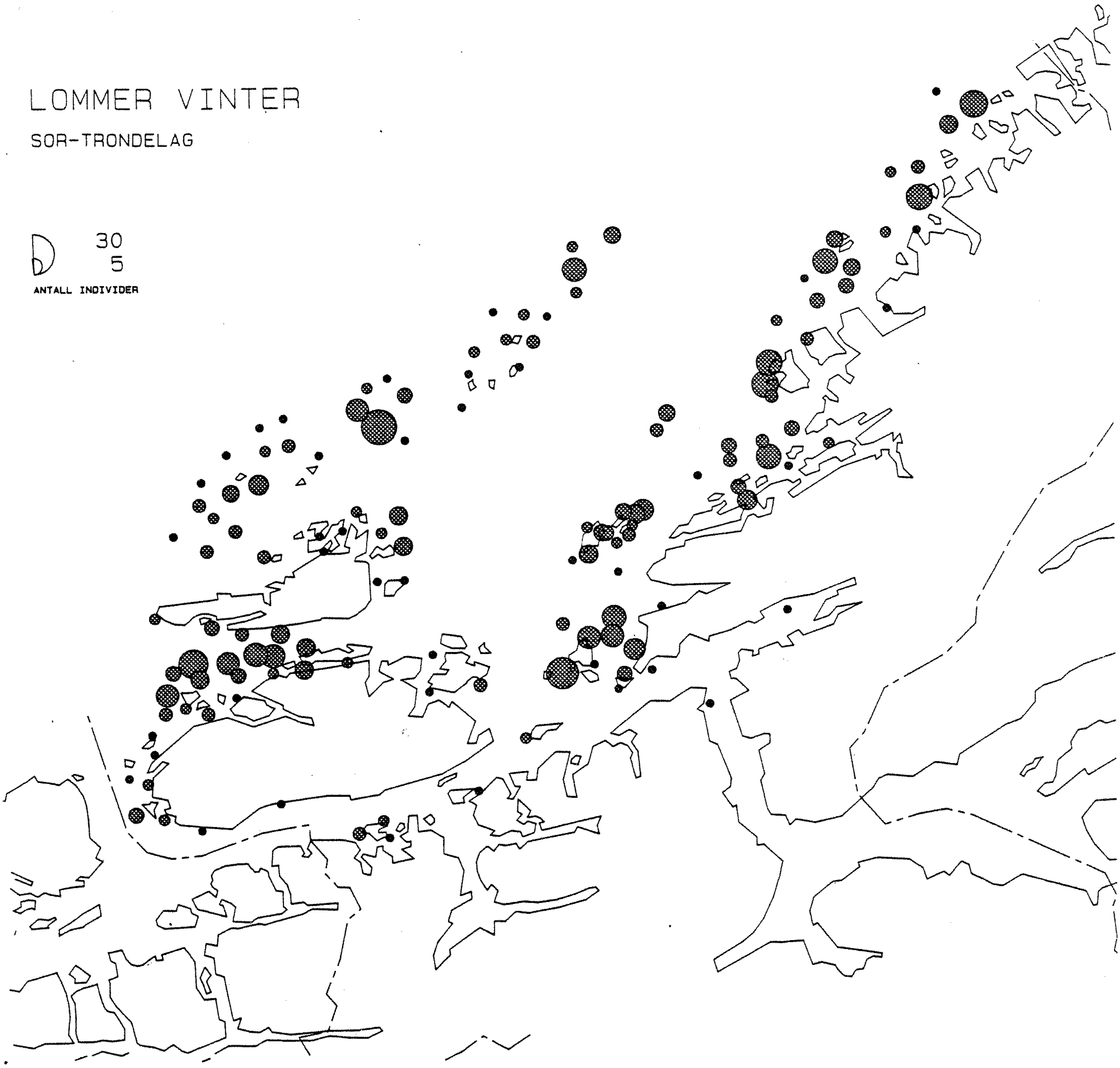


Fig. 2.34. Distribution of wintering Divers <u>Gavia sp.</u> in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

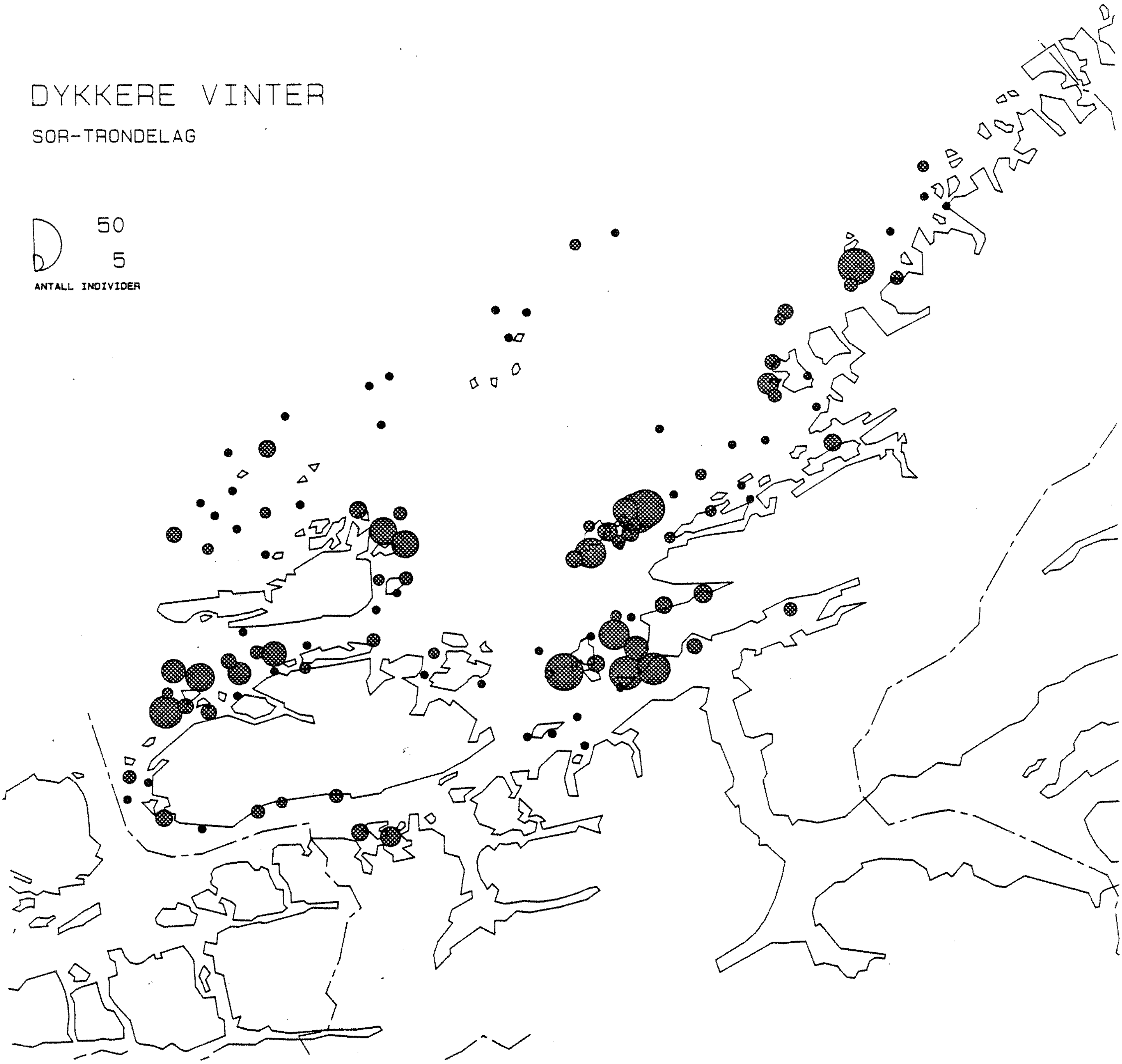


Fig. 2.35 Distribution of wintering Grebes <u>Podiceps sp.</u> in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

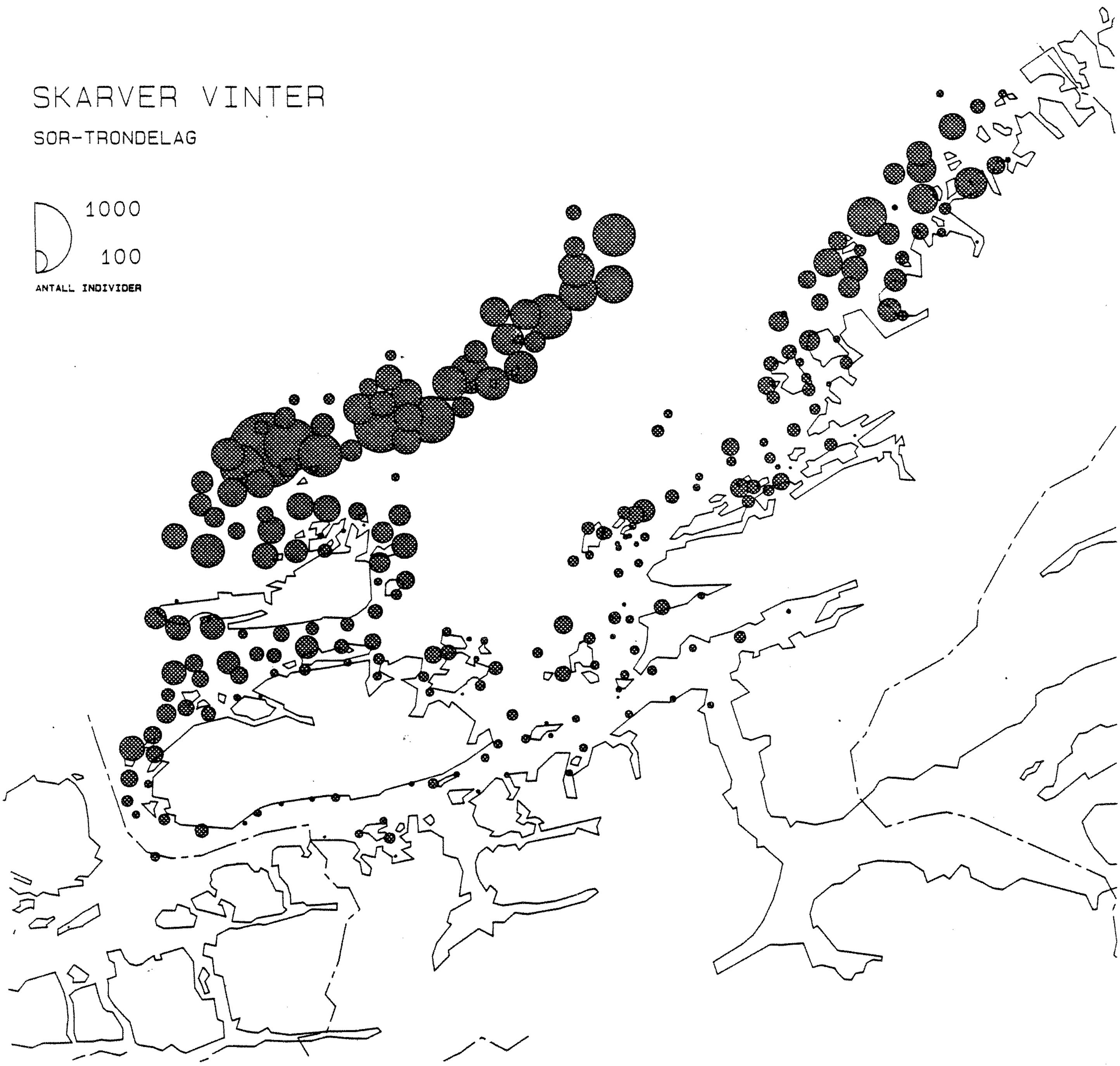


Fig. 2.36 . Distribution of wintering Shags <u>Phalacrocorax sp.</u> in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

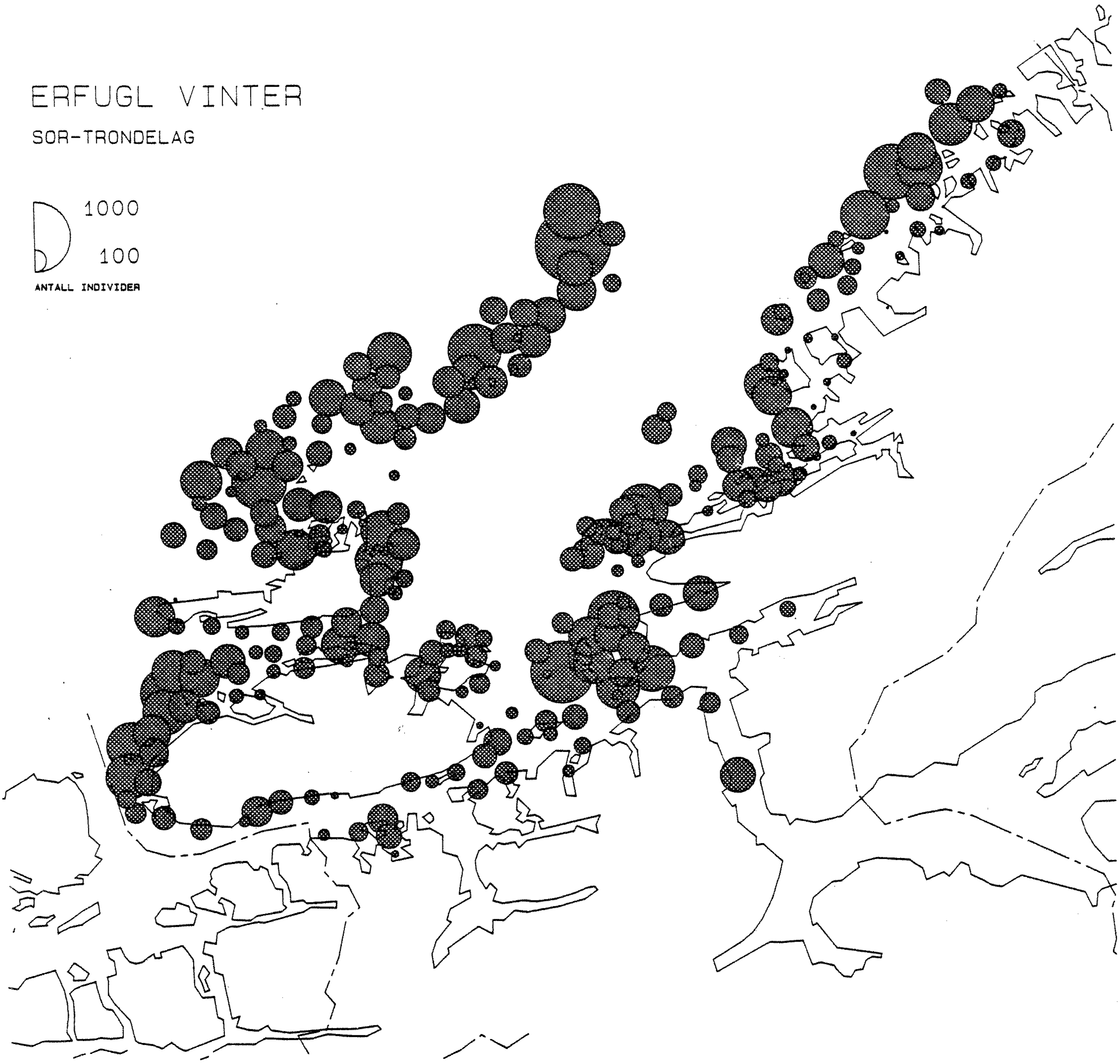


Fig. 2.37 Distribution of wintering Eiders Somateria mollissima in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

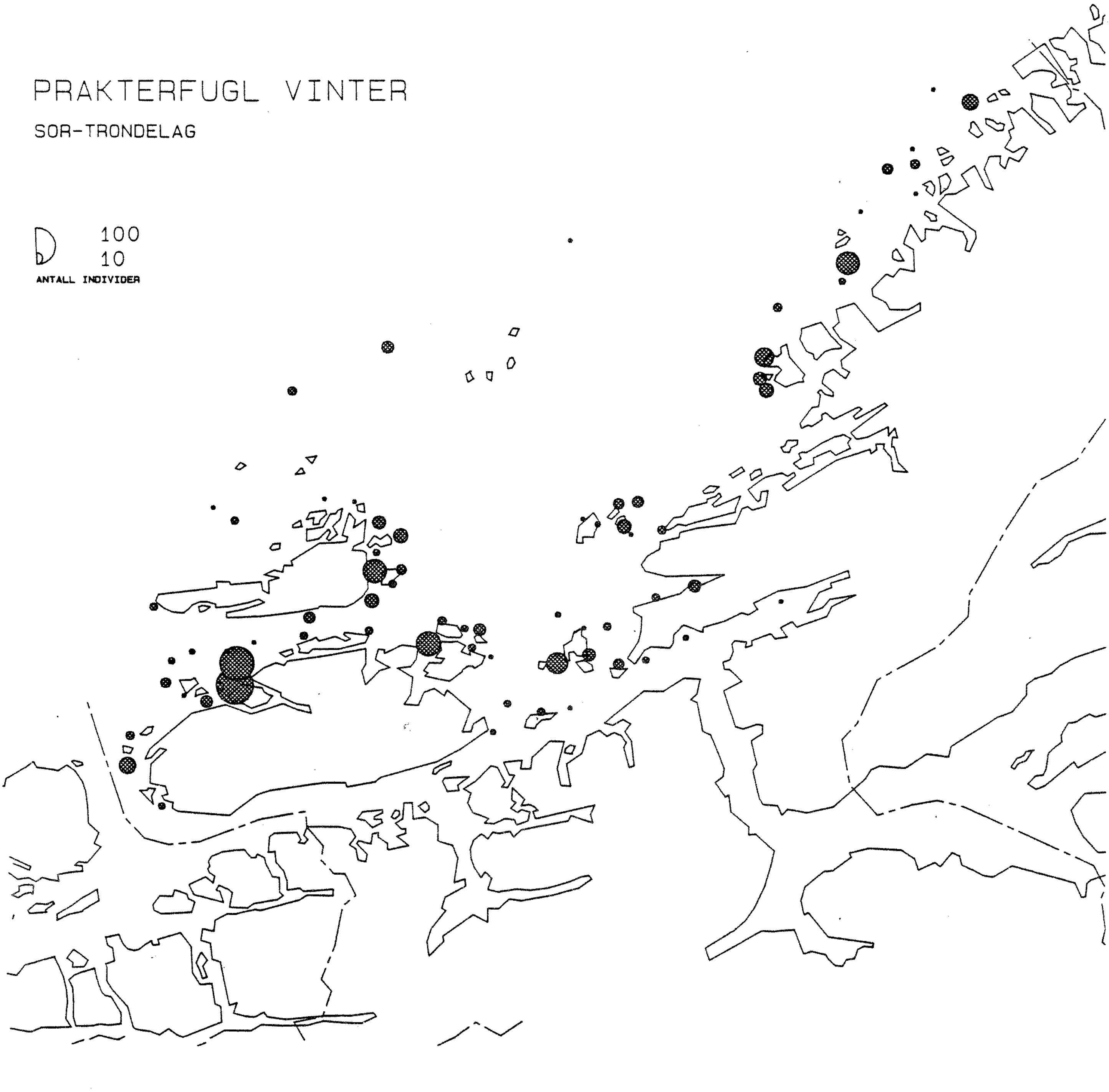


Fig. 2.38 Distribution of wintering King Eiders *Somateria spectabilis* in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

Fig. 2.39 . Distribution of wintering Velvet Scoters _Melanitta fusca_ in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

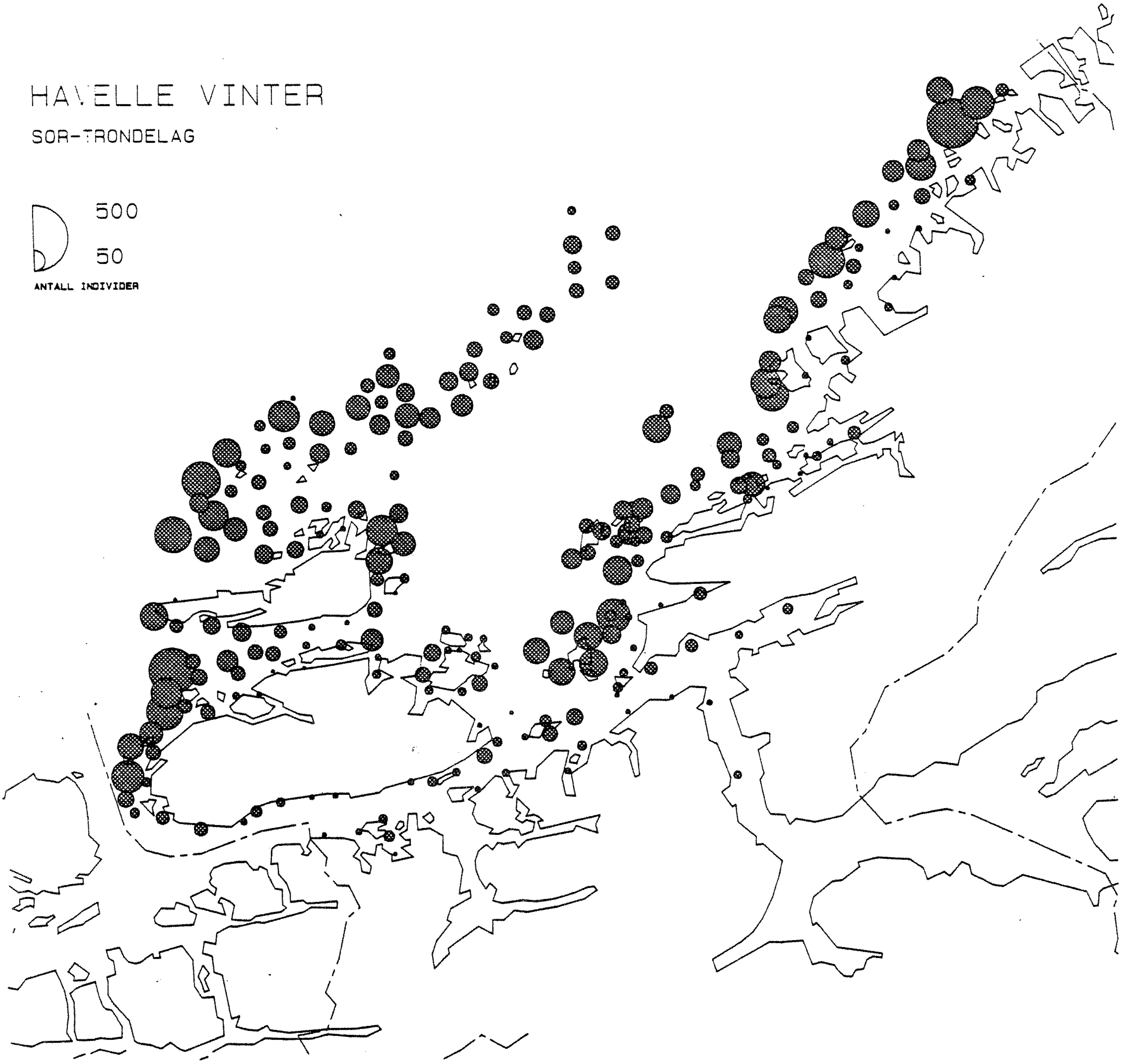


Fig. 2.40 . Distribution of wintering Long-tailed Ducks <u>Clangula hyemalis</u> in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

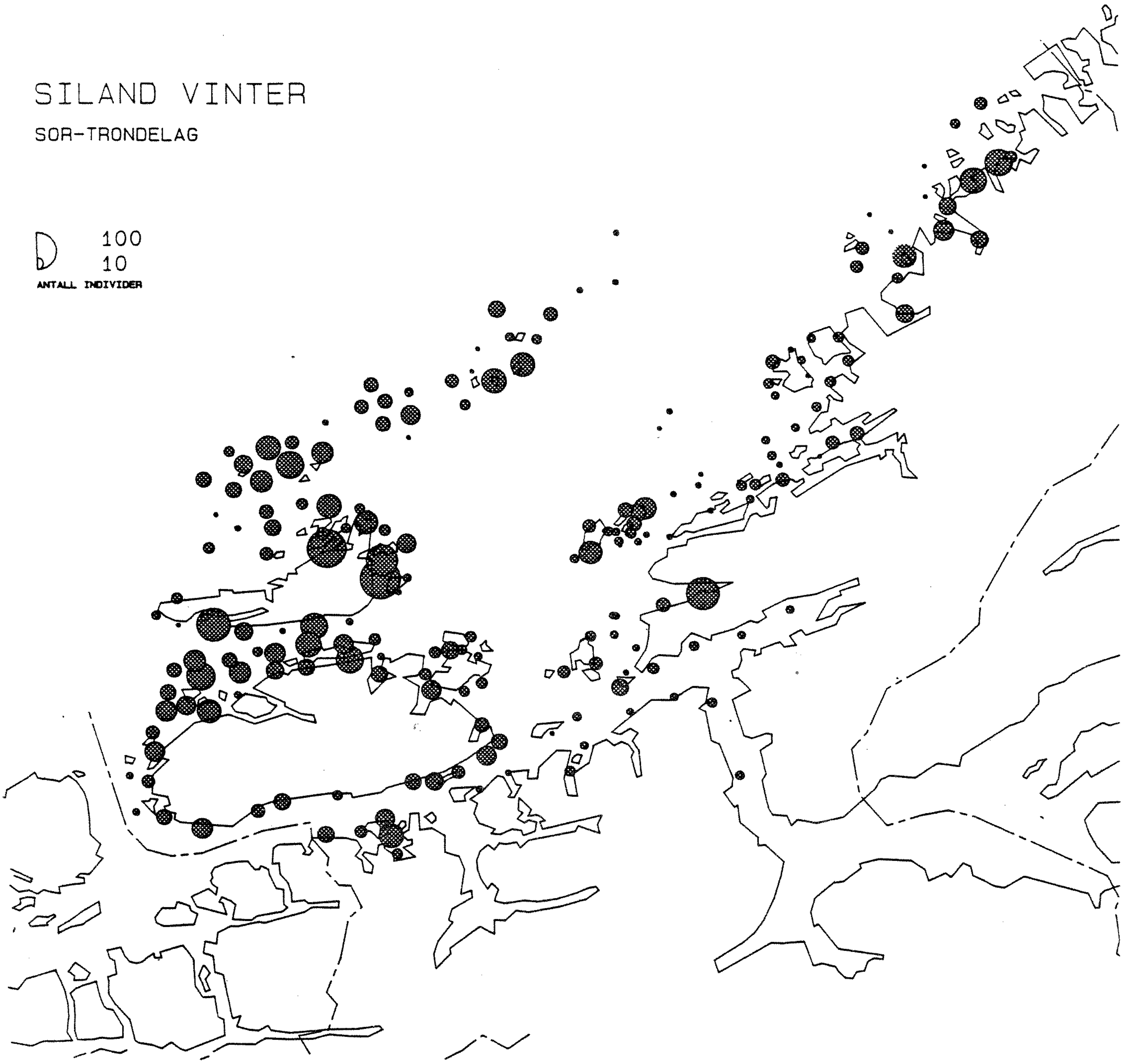


Fig. 2.41 Distribution of wintering Red-breasted Mergansers <u>Mergus serrator</u> in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

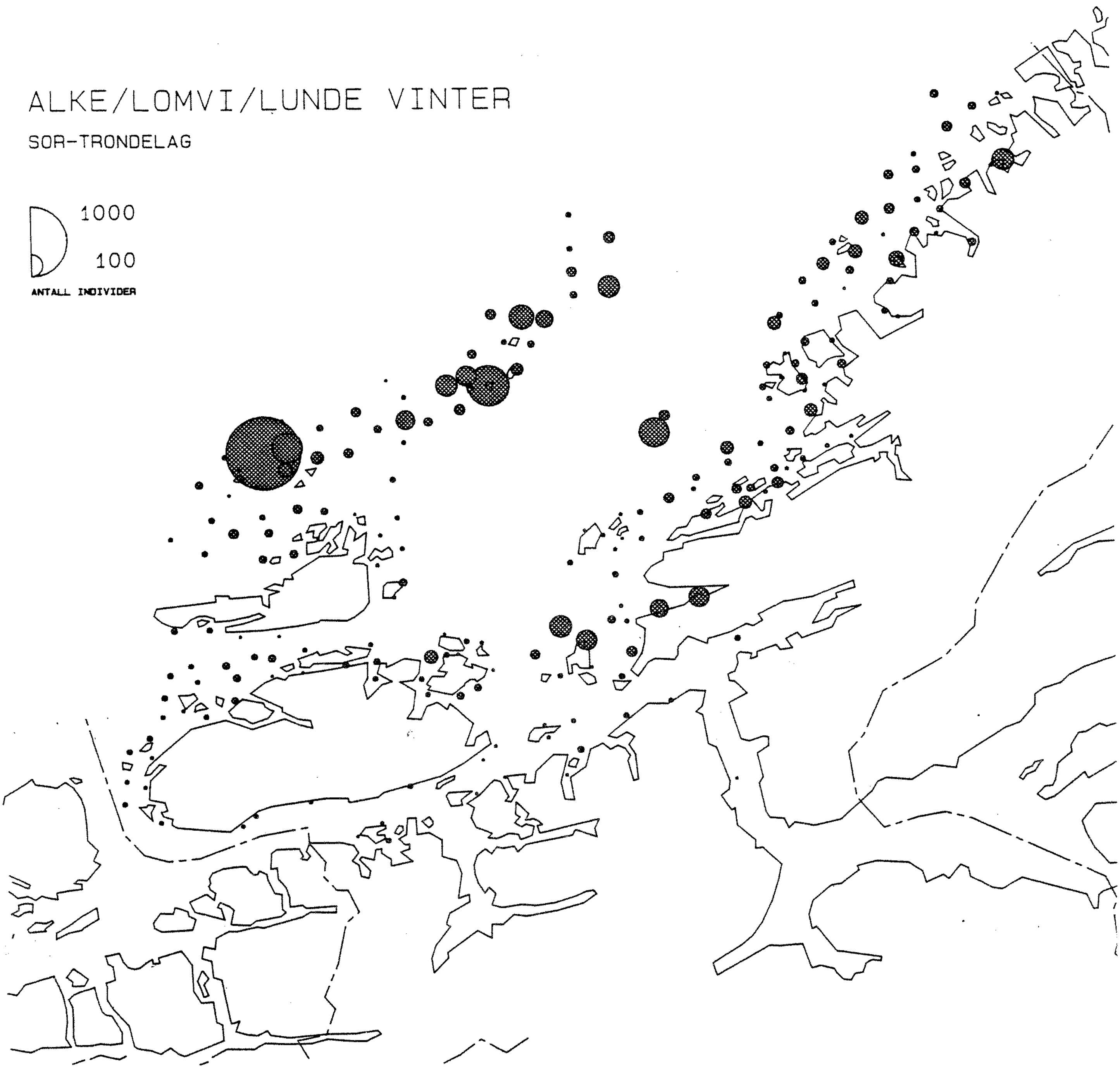


Fig. 2.42 Distribution of wintering Razorbills <u>Alca torda</u>, Guillemots <u>Uria aalge</u> and Puffins <u>Fratercula arctica</u> in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

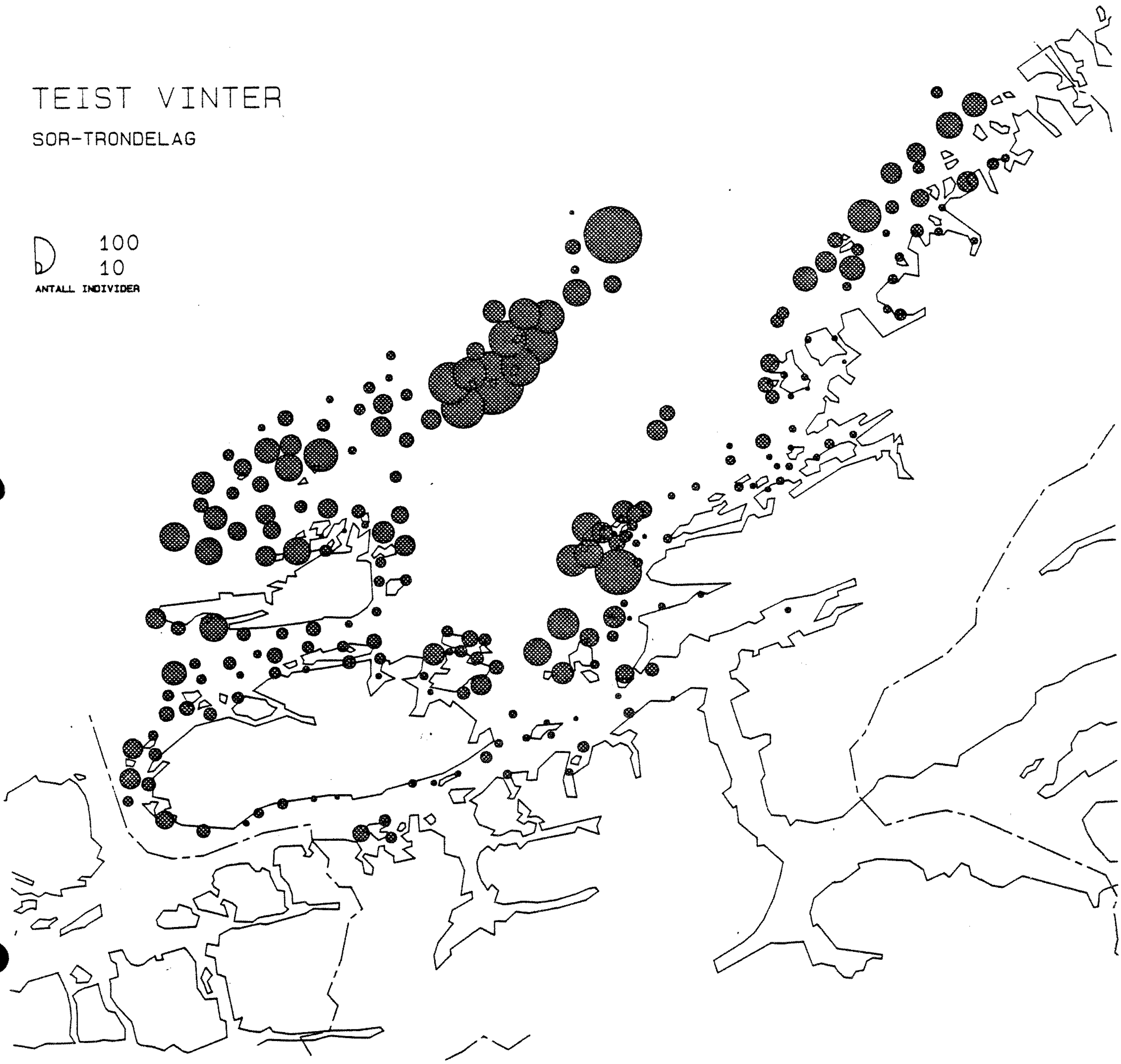


Fig. 2.43 Distribution of wintering Black Guillemots <u>Cepphus grylle</u> in Sør-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

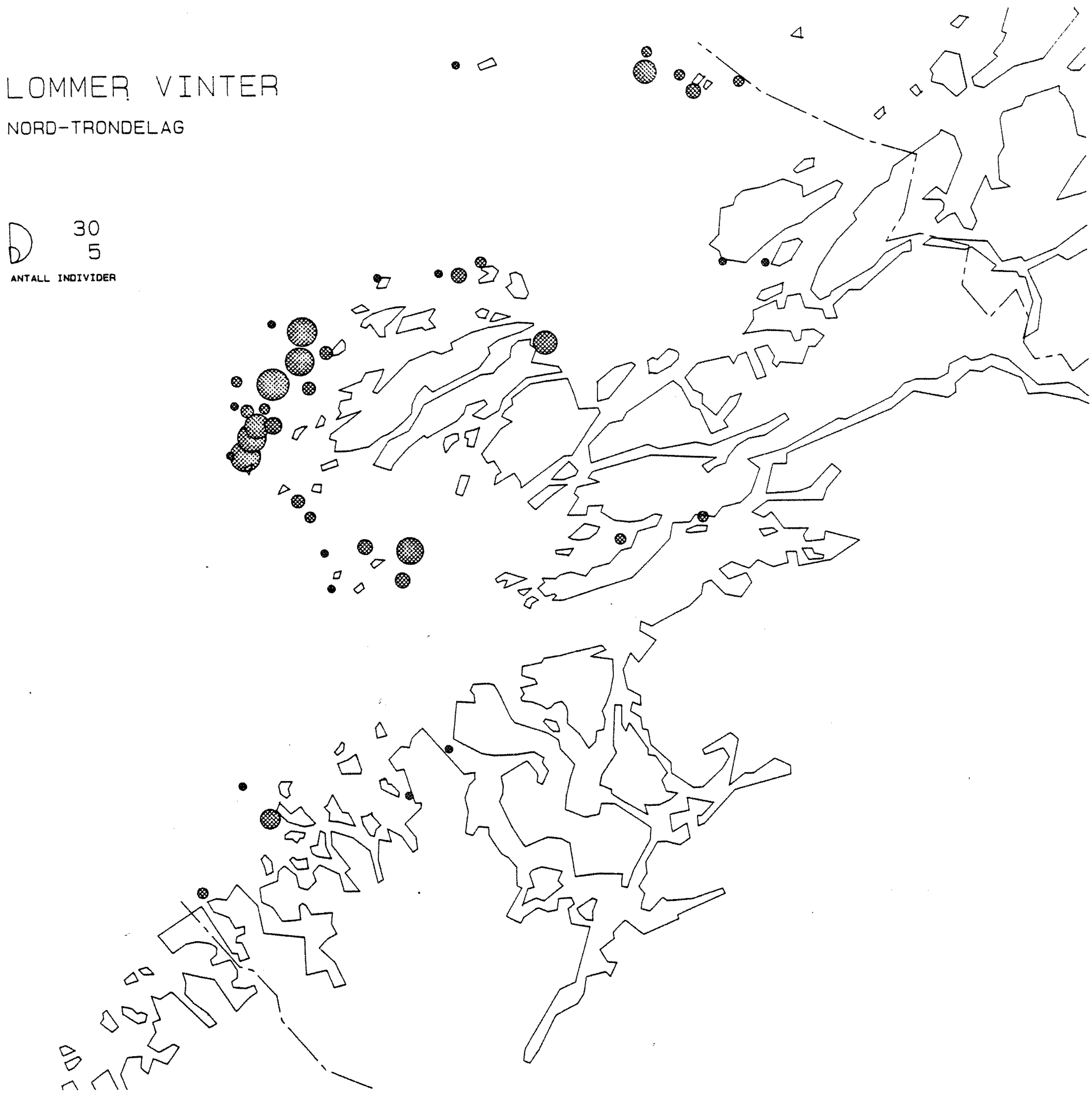


Fig. 2.44 Distribution of wintering Divers Gavia sp. in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

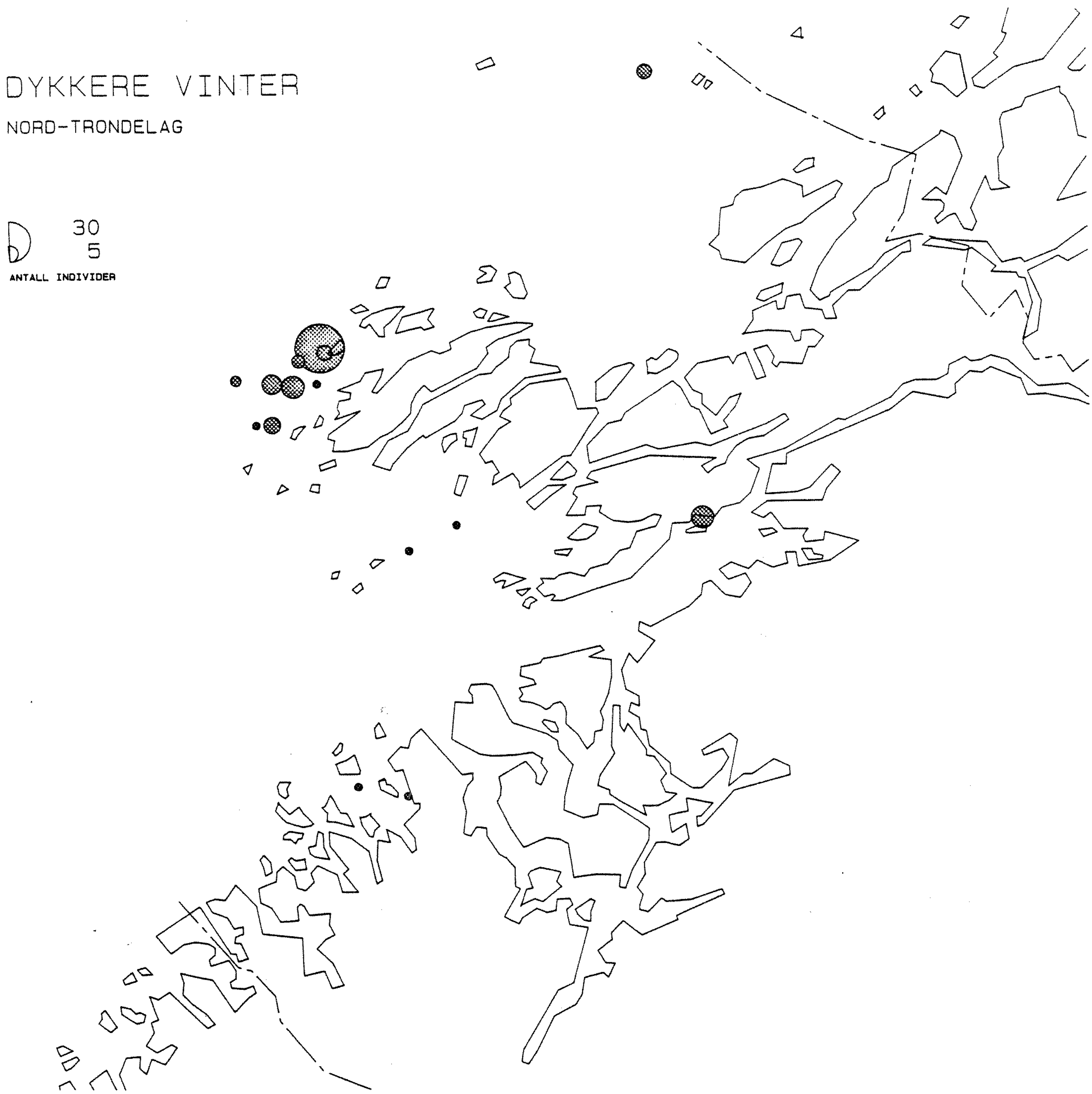


Fig. 2.45 Distribution of wintering Grebes Podiceps sp. in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

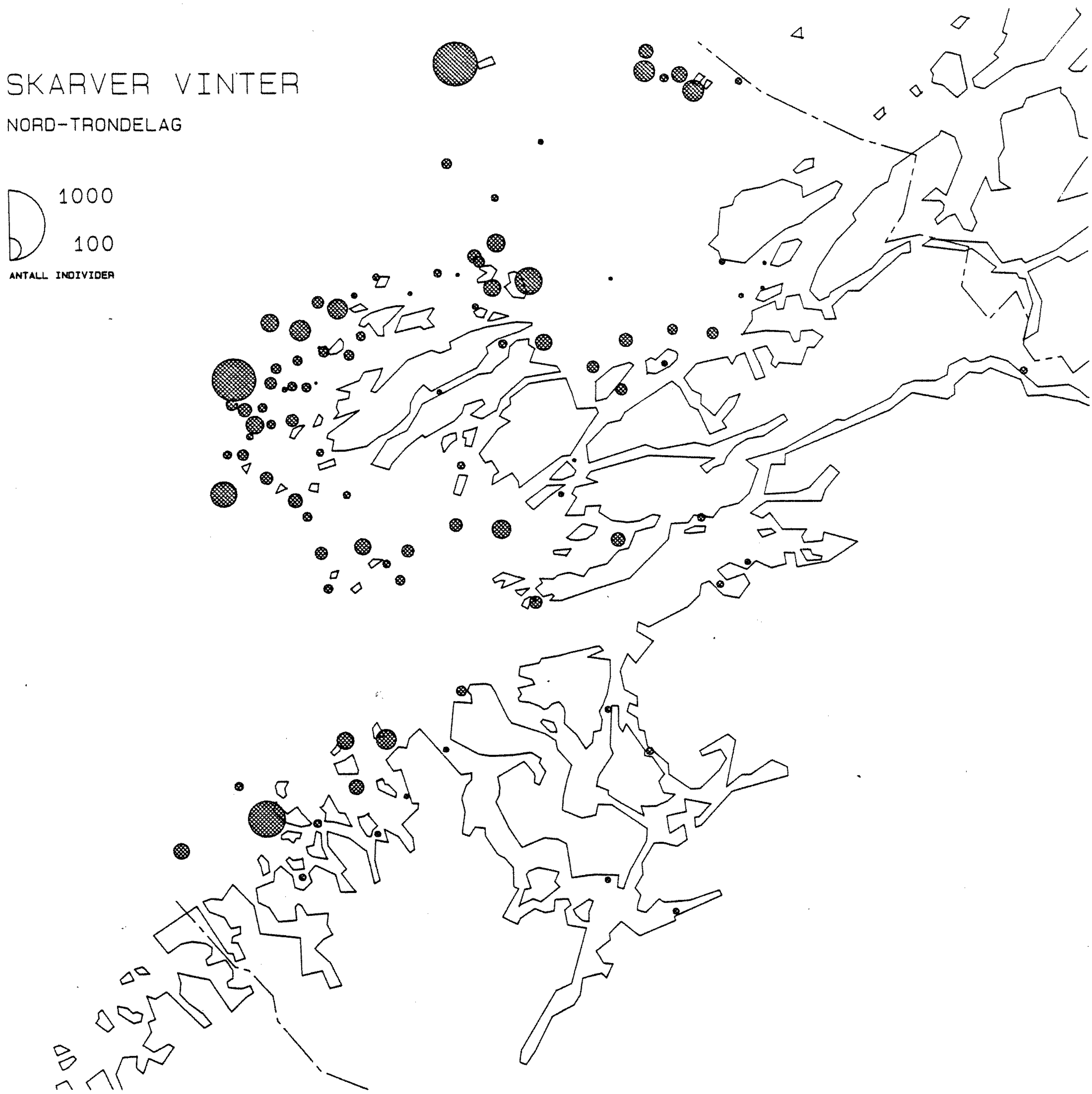


Fig. 2.46 Distribution of wintering Shags *Phalacrocorax sp.* in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

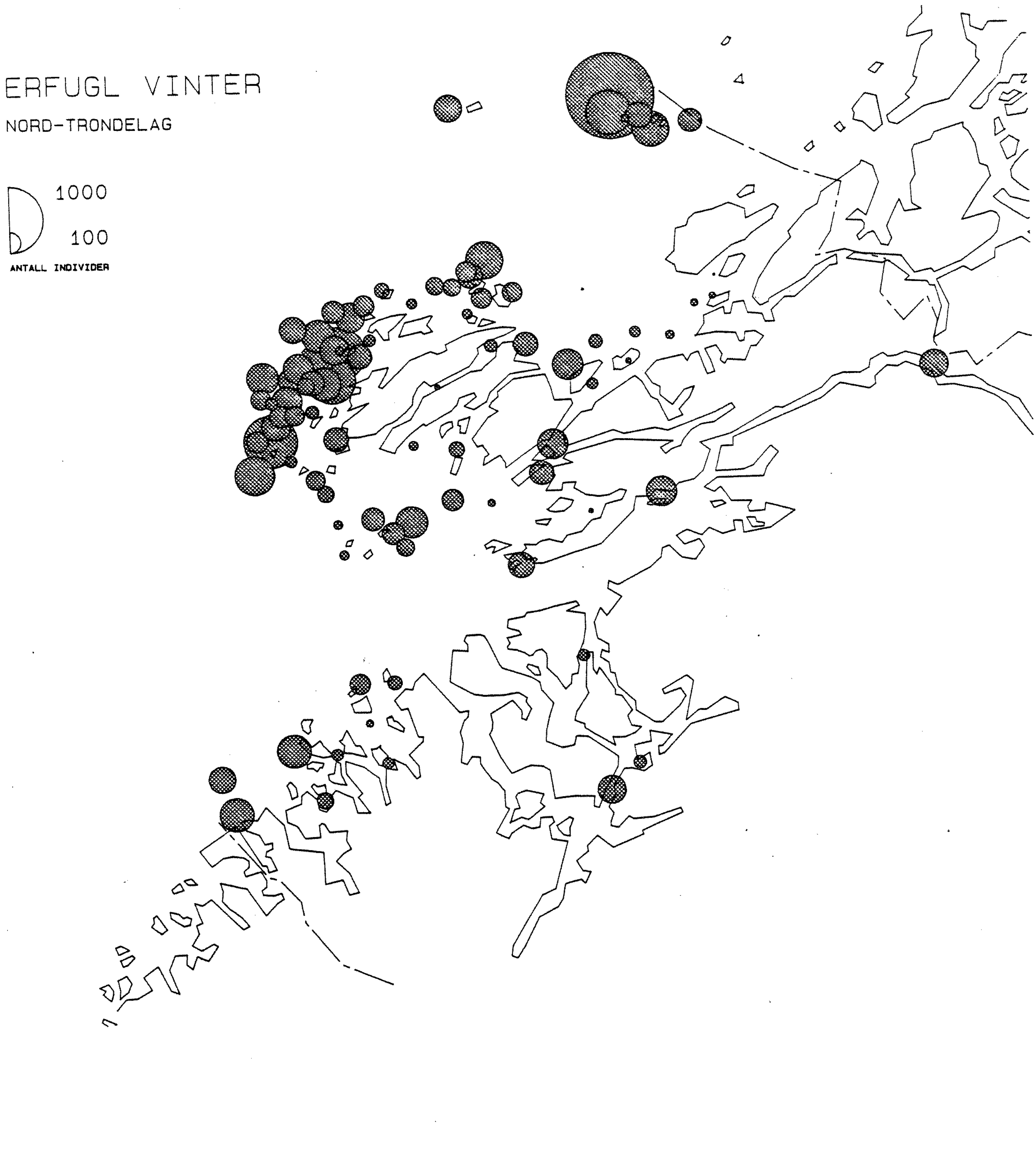


Fig. 2.47 Distribution of wintering Eiders <u>Somateria mollissima</u> in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

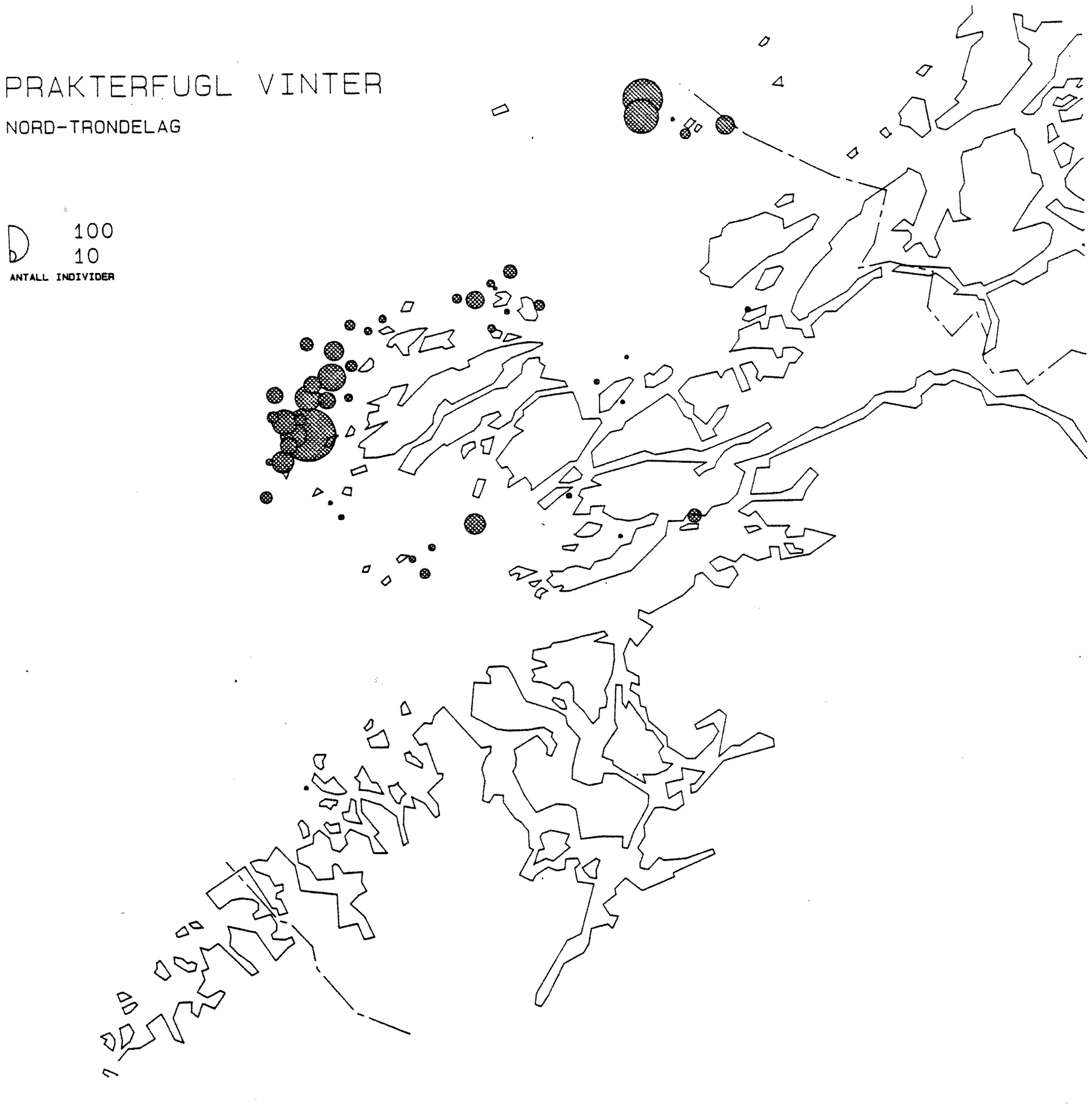


Fig. 2.48 Distribution of wintering King Eiders <u>Somateria spectabilis</u> in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

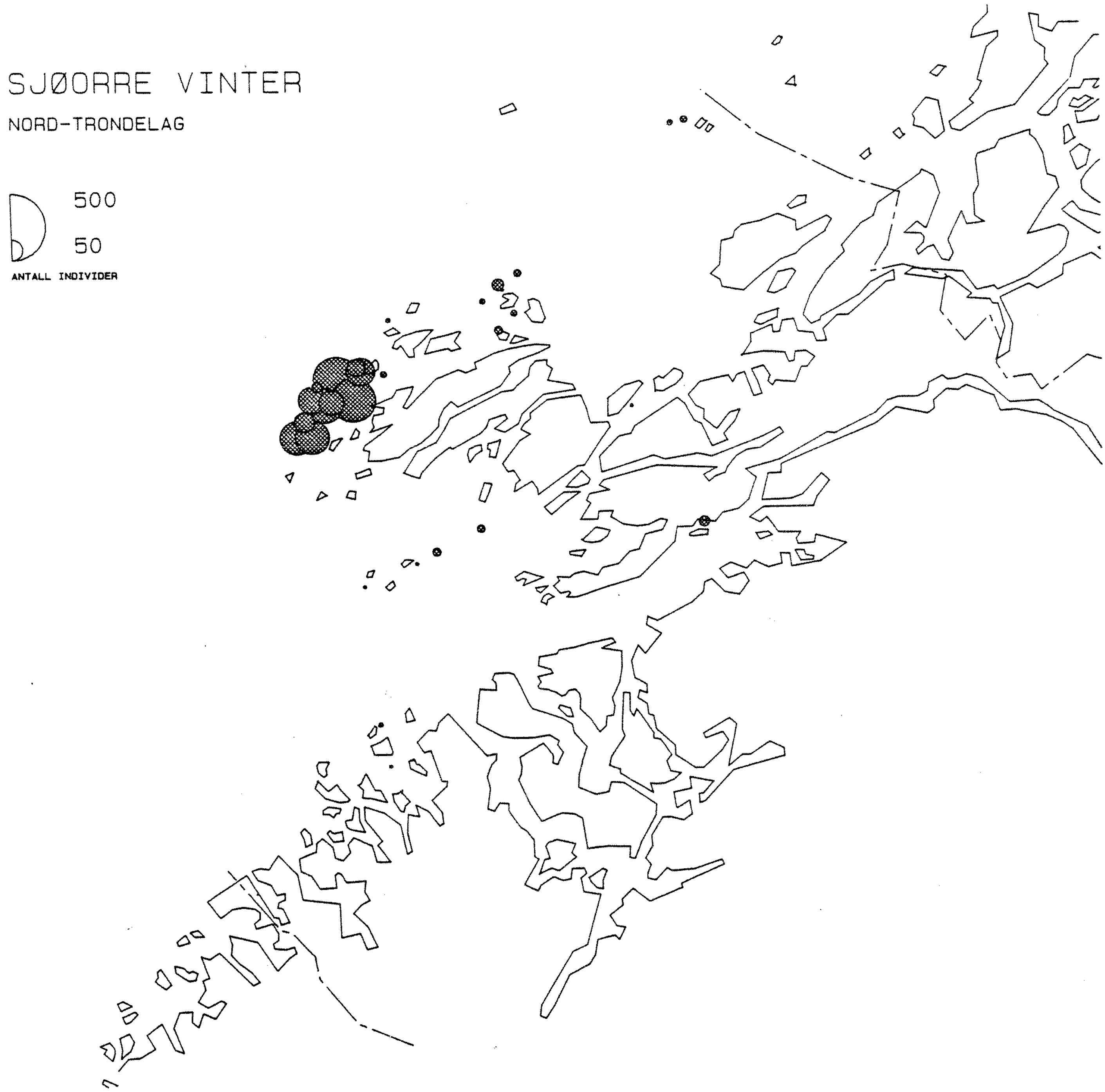


Fig. 2.49 Distribution of wintering Velvet Scoters <u>Melanitta fusca</u> in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

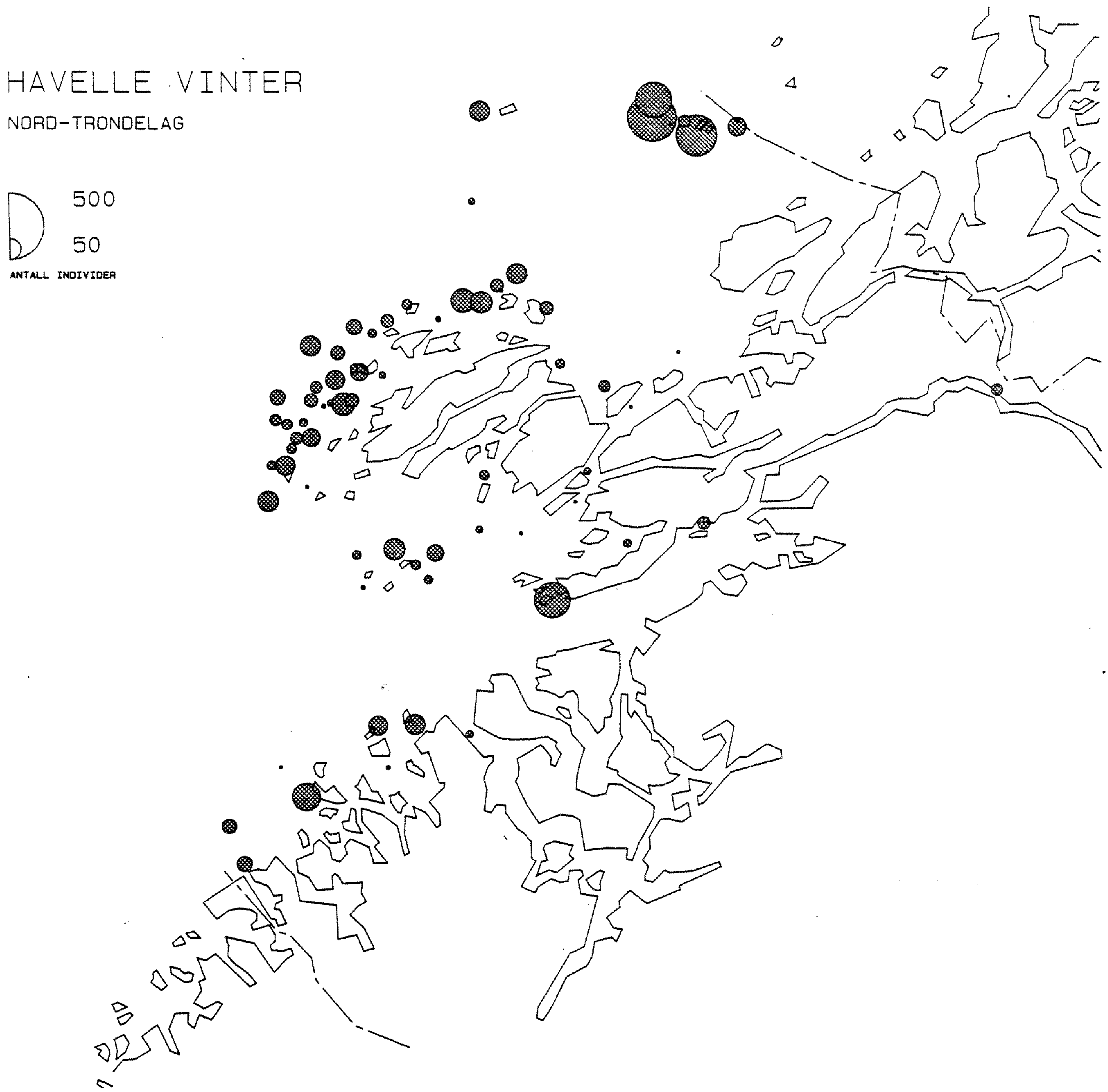


Fig. 2.50 Distribution of wintering Long-tailed Ducks <u>Clangula hyemalis</u> in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

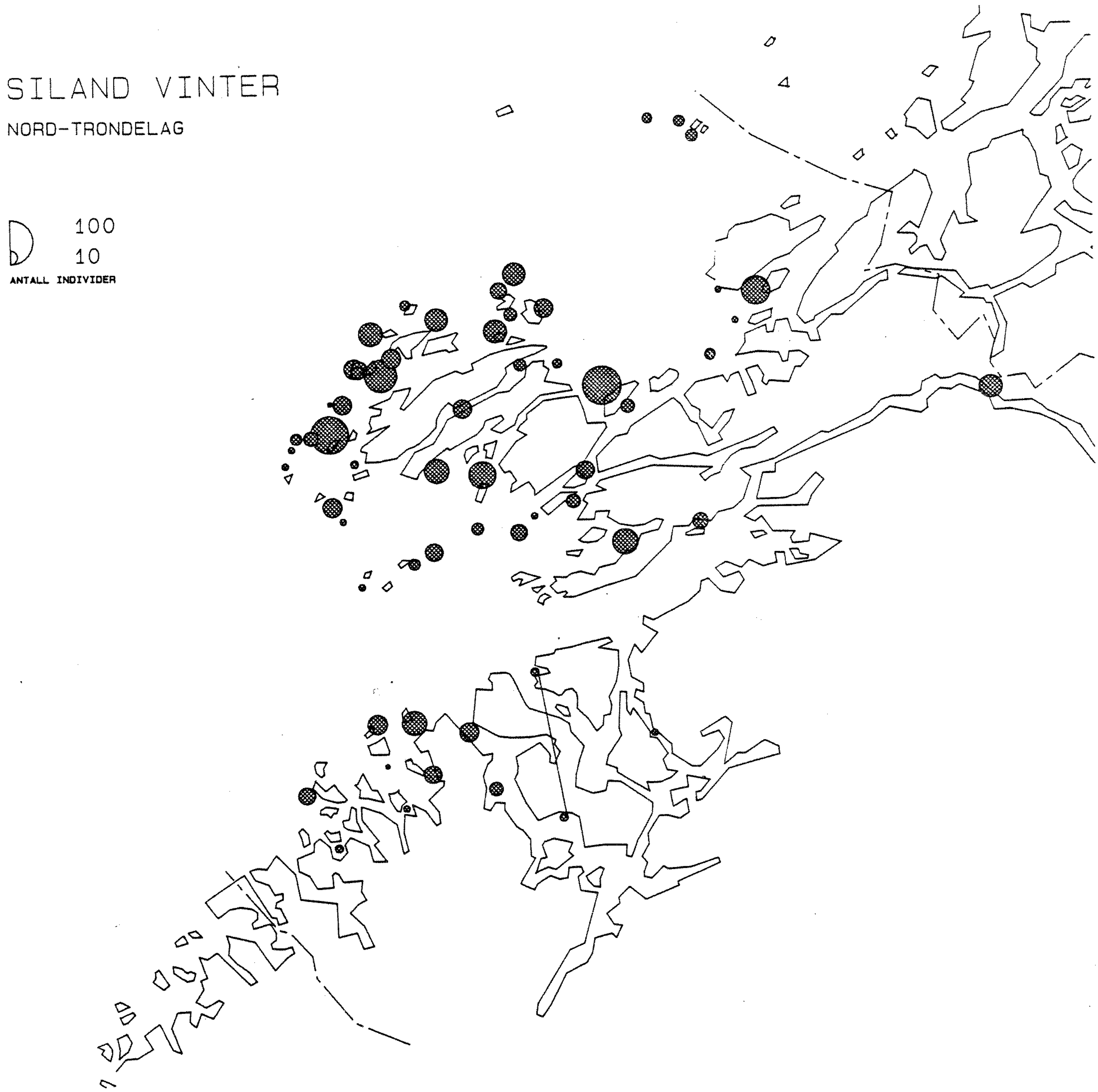


Fig. 2.51 Distribution of wintering Red-breasted Mergansers Mergus serrator in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

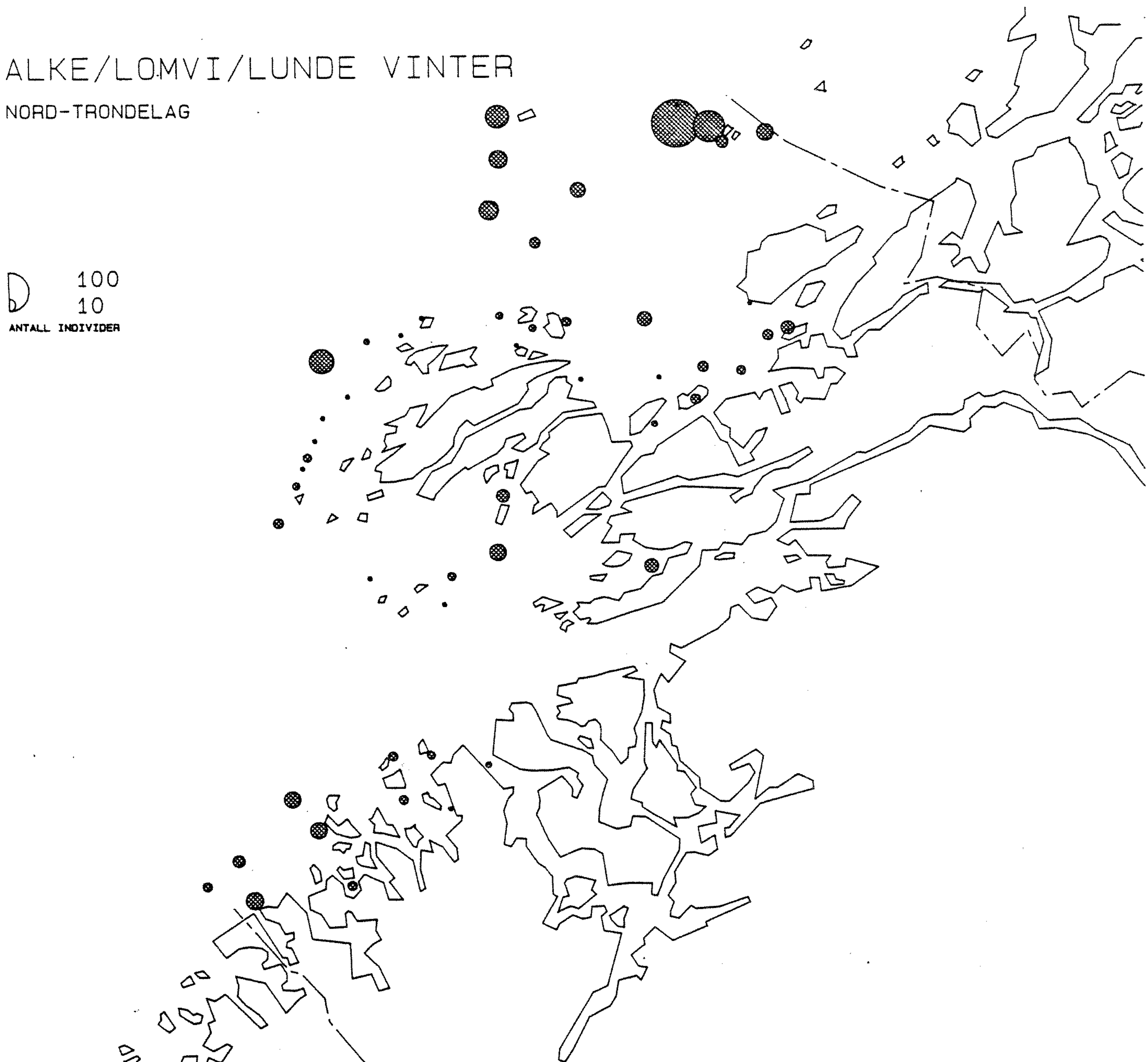


Fig. 2.52 Distribution of wintering Razorbills Alca torda, Guillemots Uria aalge and Puffins Fratercula arctica in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

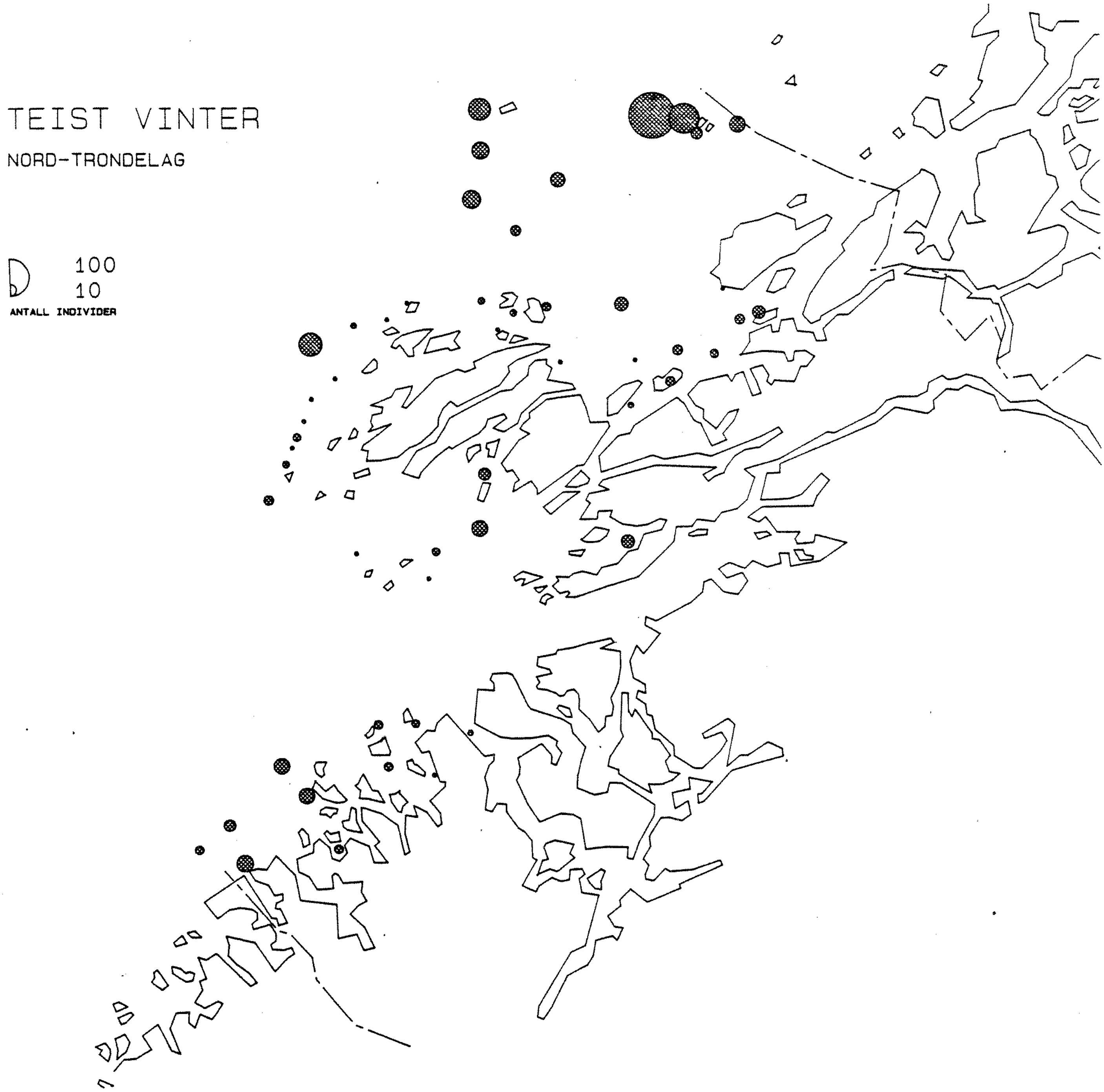


Fig. 2.53 Distribution of wintering Black Guillemots <u>Cepphus grylle</u> in Nord-Trøndelag. Scale refers to circle diameter and represents no. of individuals.

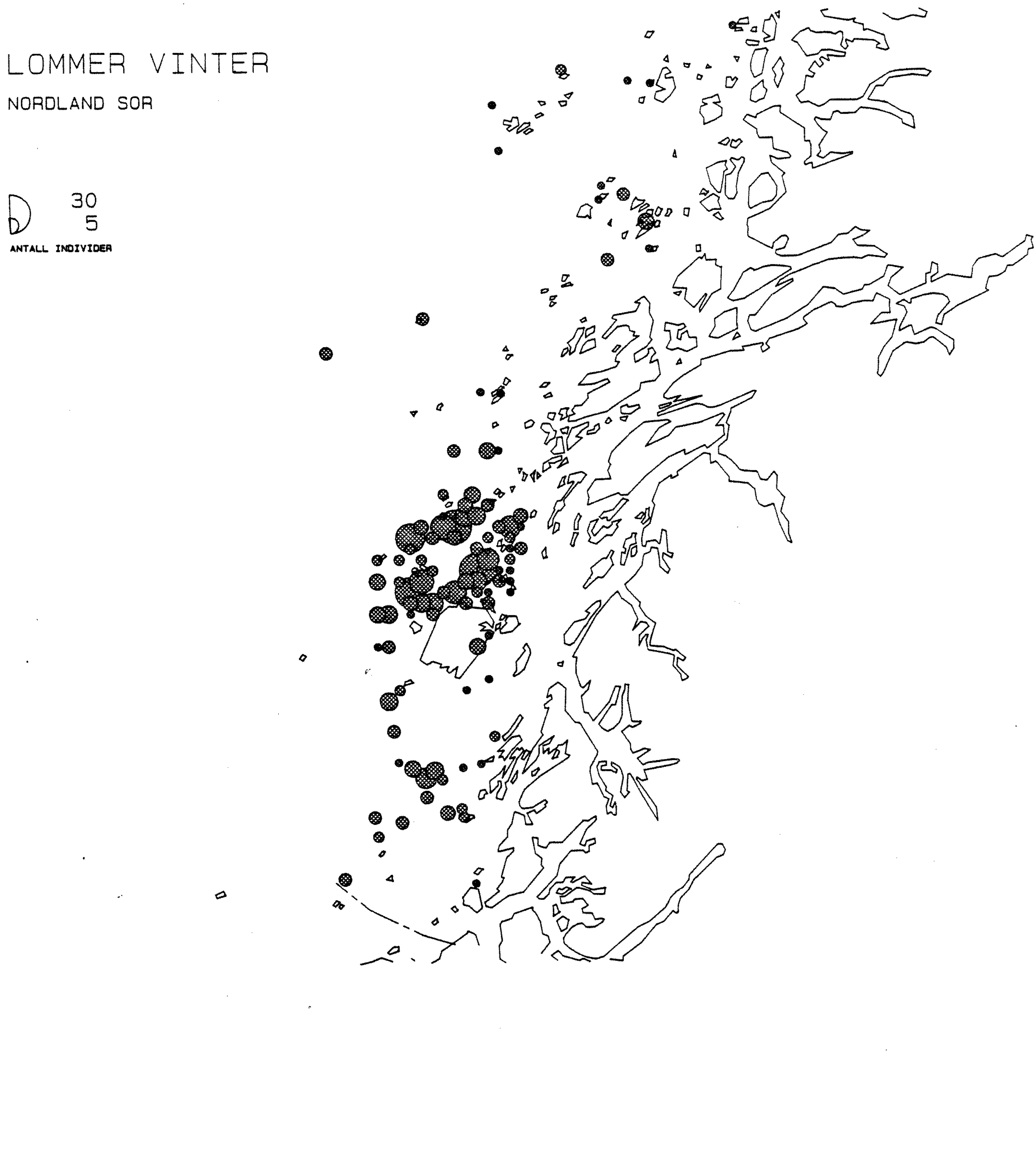


Fig. 2.54 Distribution of wintering Divers <u>Gavia sp.</u> in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

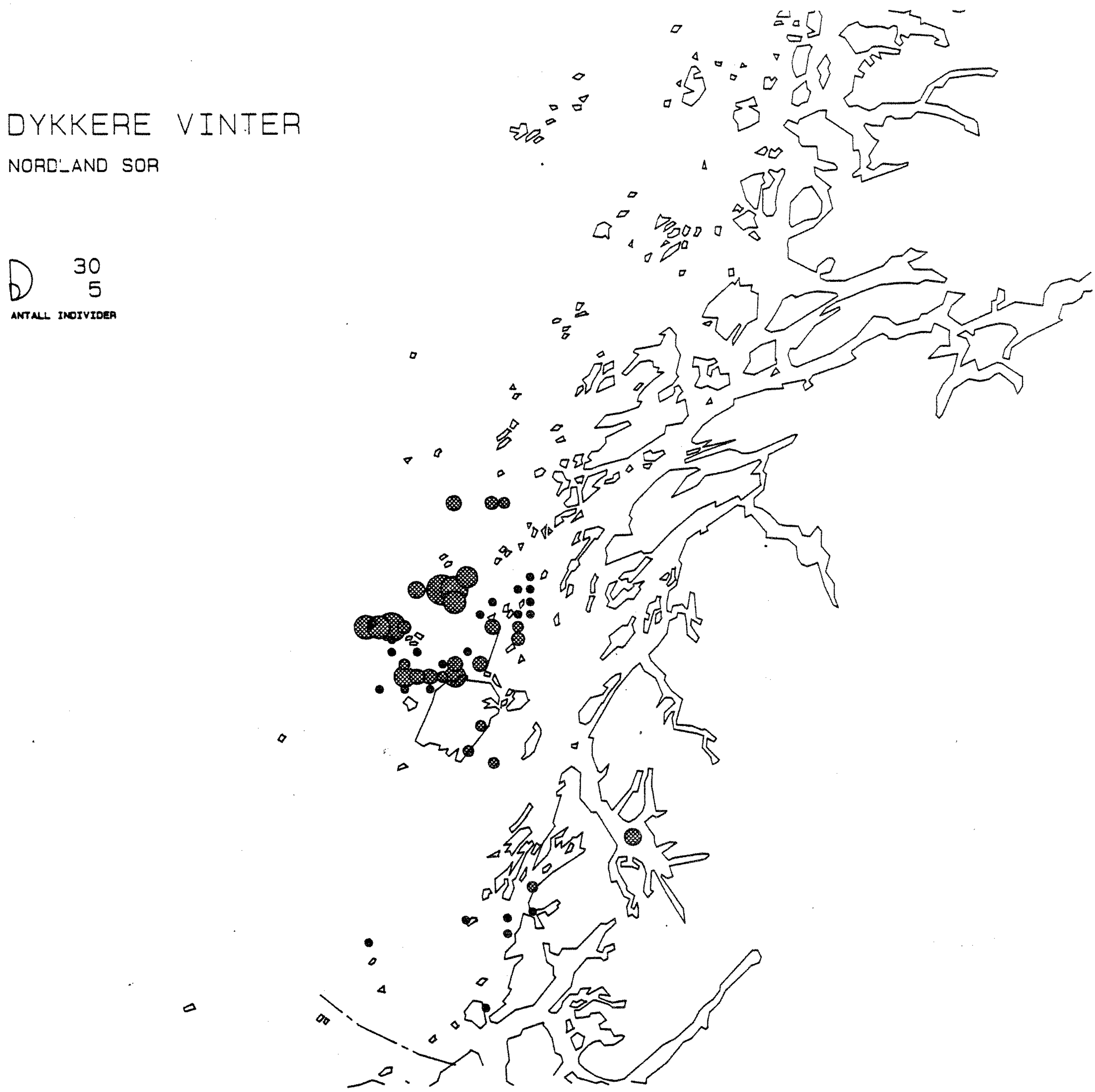


Fig. 2.55 Distribution of wintering Grebes <u>Podiceps sp.</u> in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

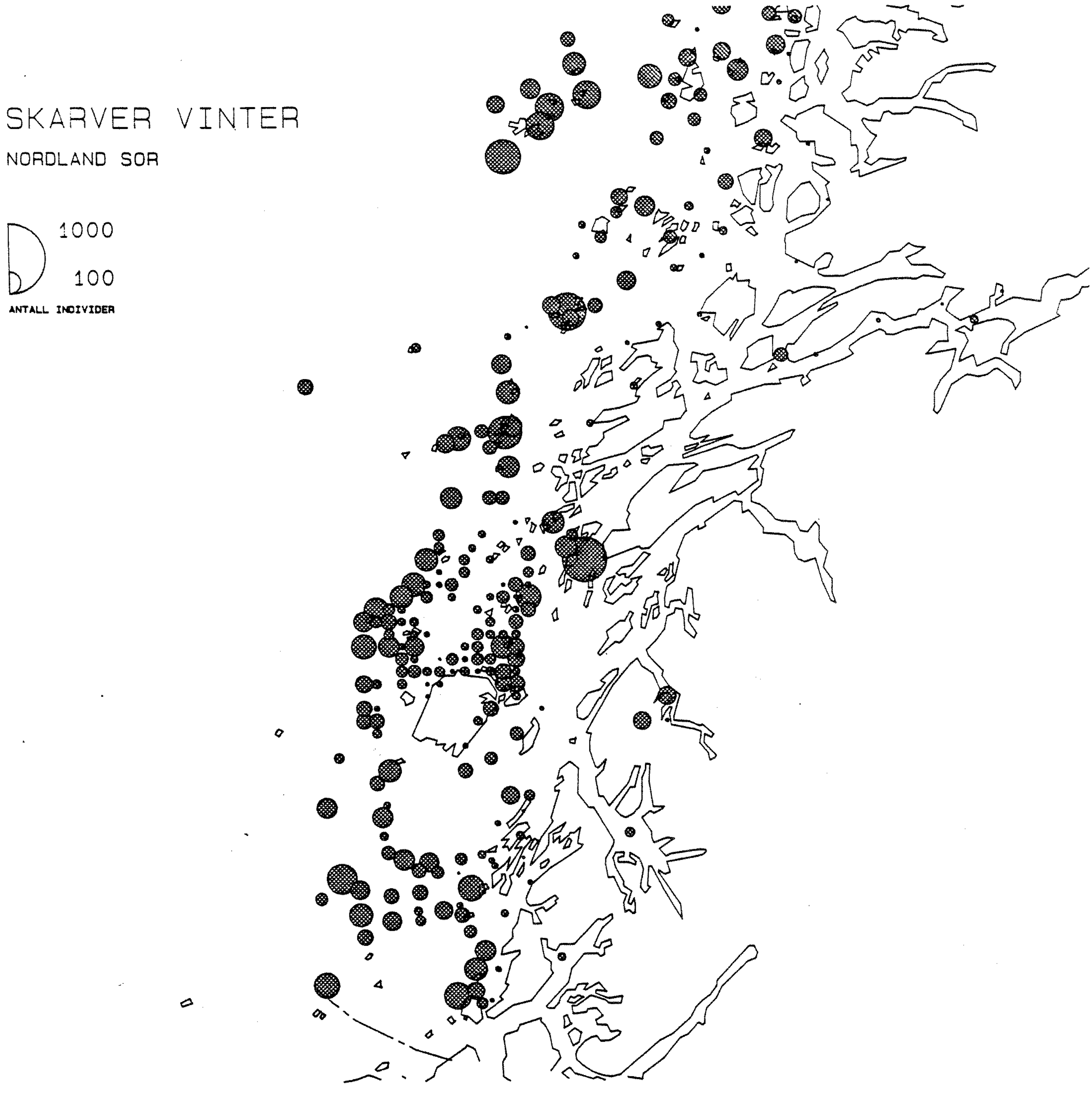


Fig. 2.56 Distribution of wintering Shags Phalacrocorax sp. in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

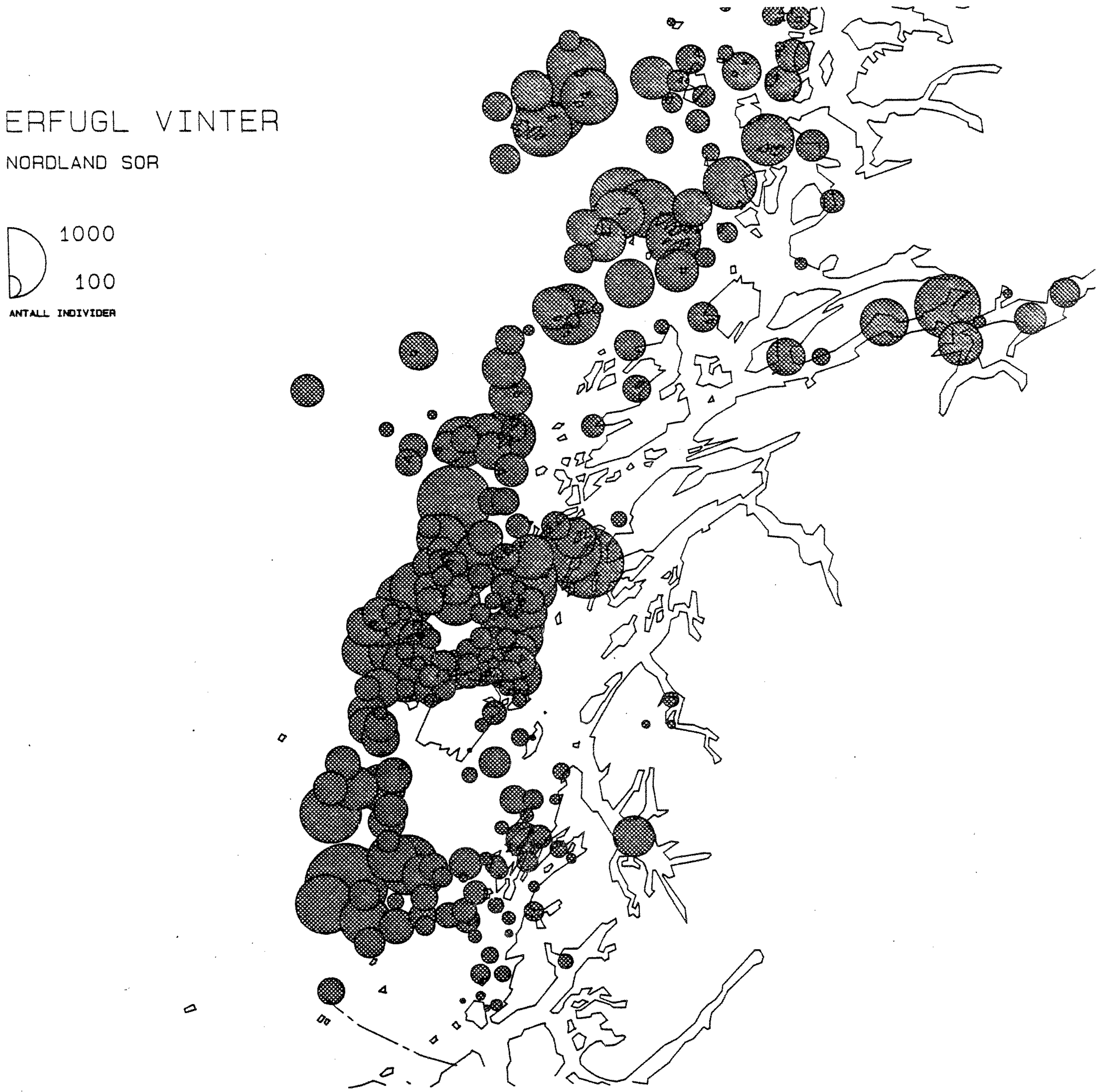


Fig. 2.57 Distribution of wintering Eiders _Somateria mollissima_ in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

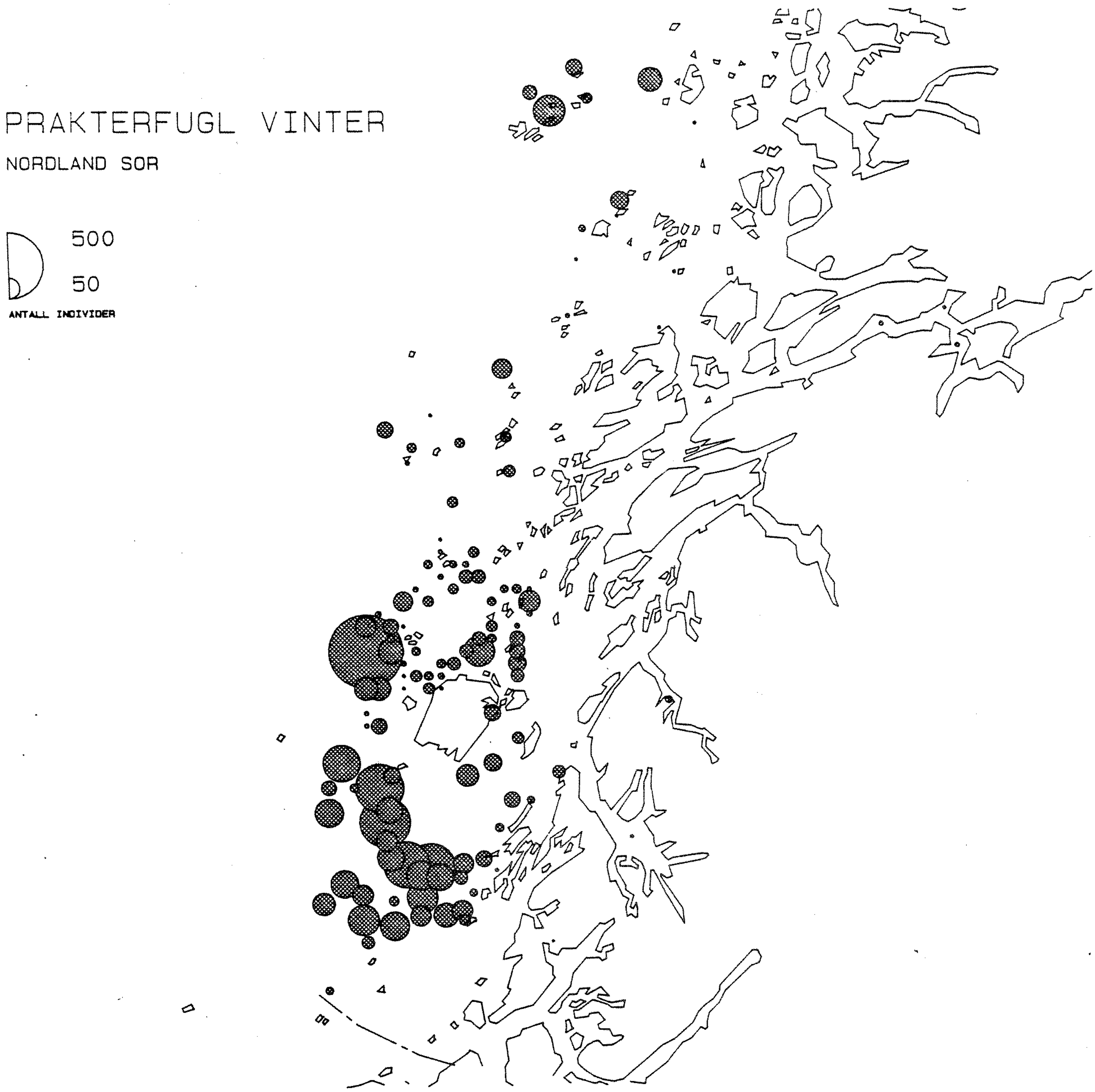


Fig. 2.58 Distribution of wintering King Eiders *Somateria spectabilis* in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

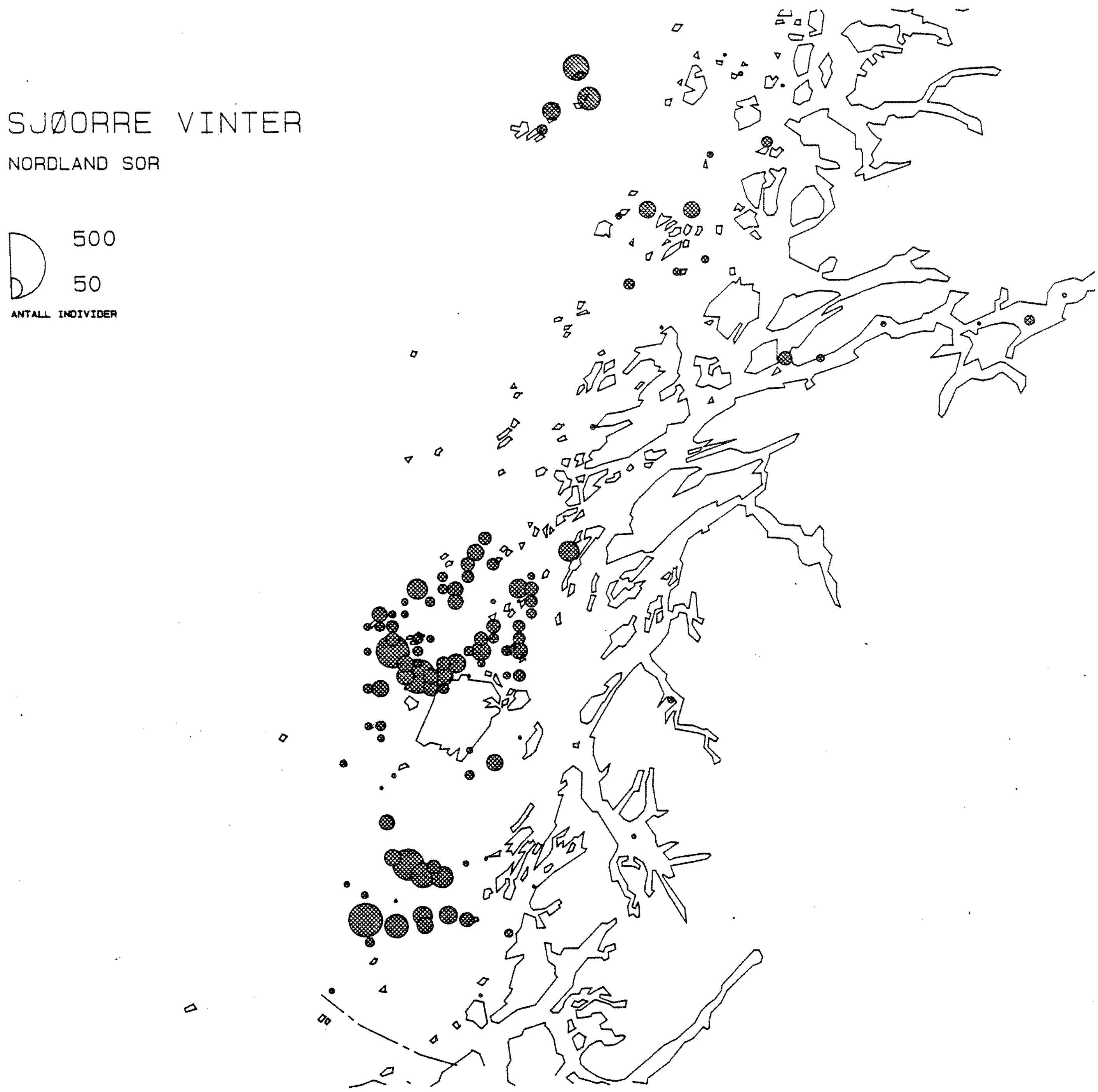


Fig. 2.59 Distribution of wintering Velvet Scoters *Melanitta fusca* in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

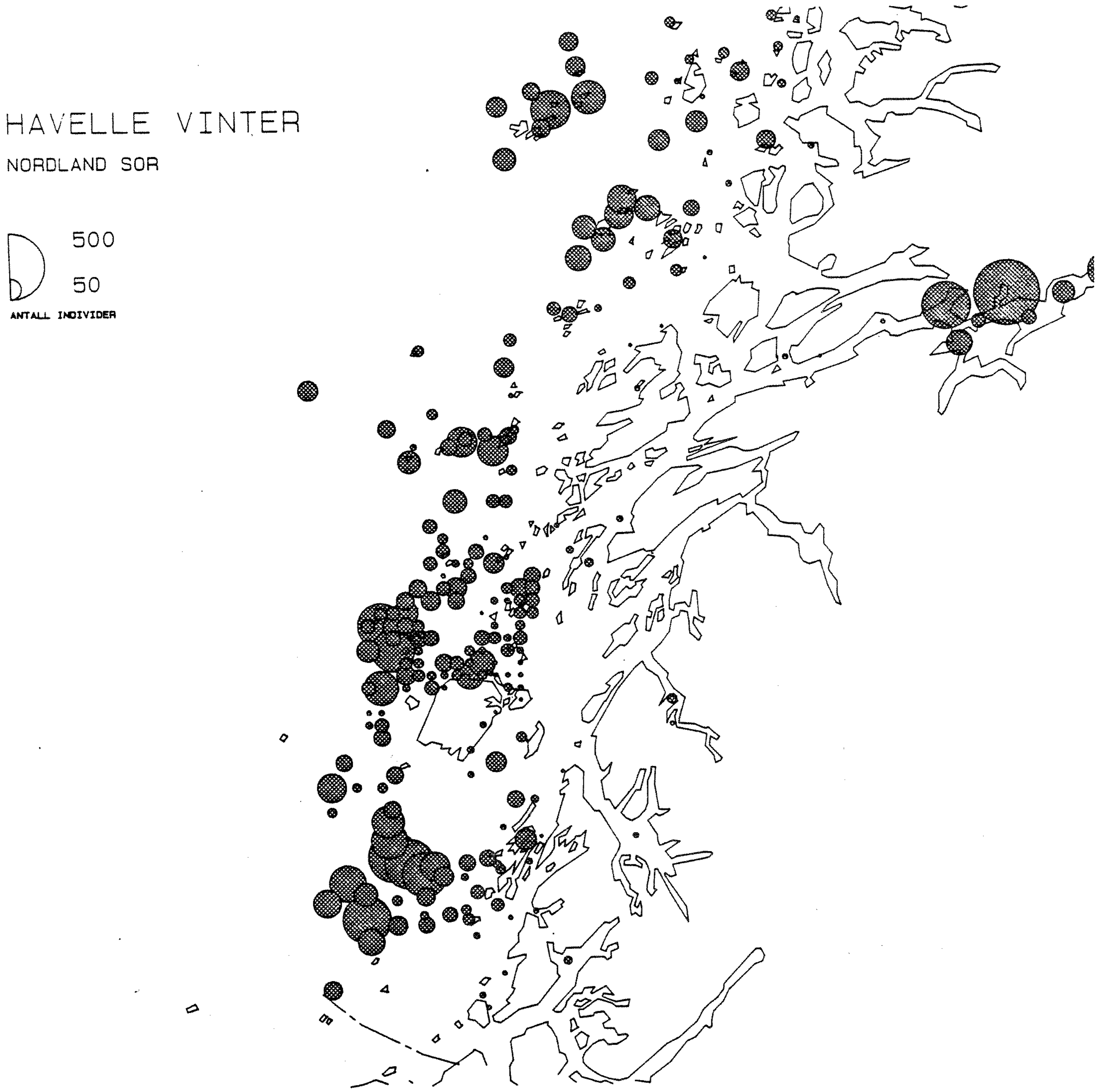


Fig. 2.60 Distribution of wintering Long-tailed Ducks <u>Clangula hyemalis</u> in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

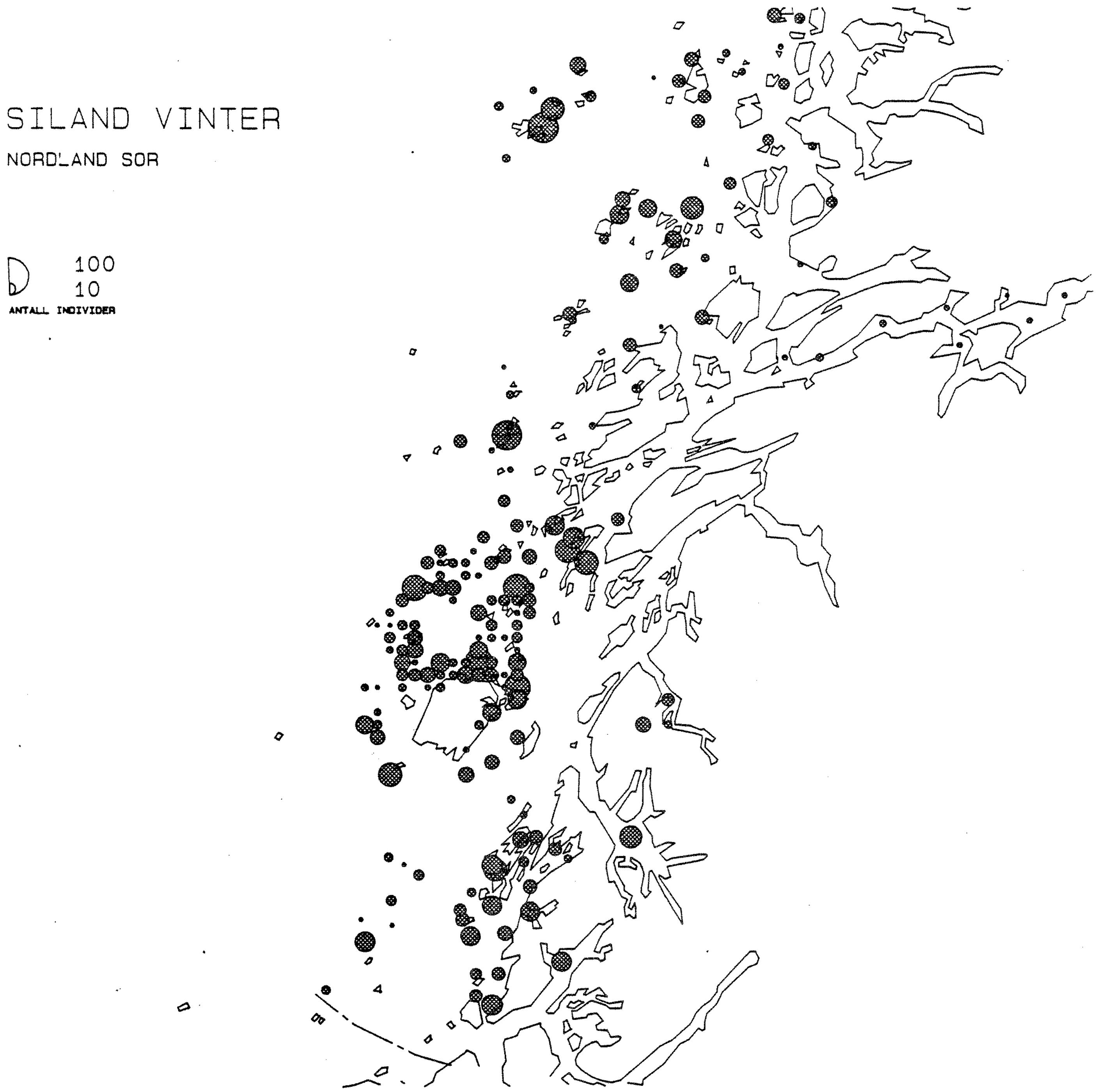


Fig. 2.61 Distribution of wintering Red-breasted Mergansers <u>Mergus serrator</u> in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

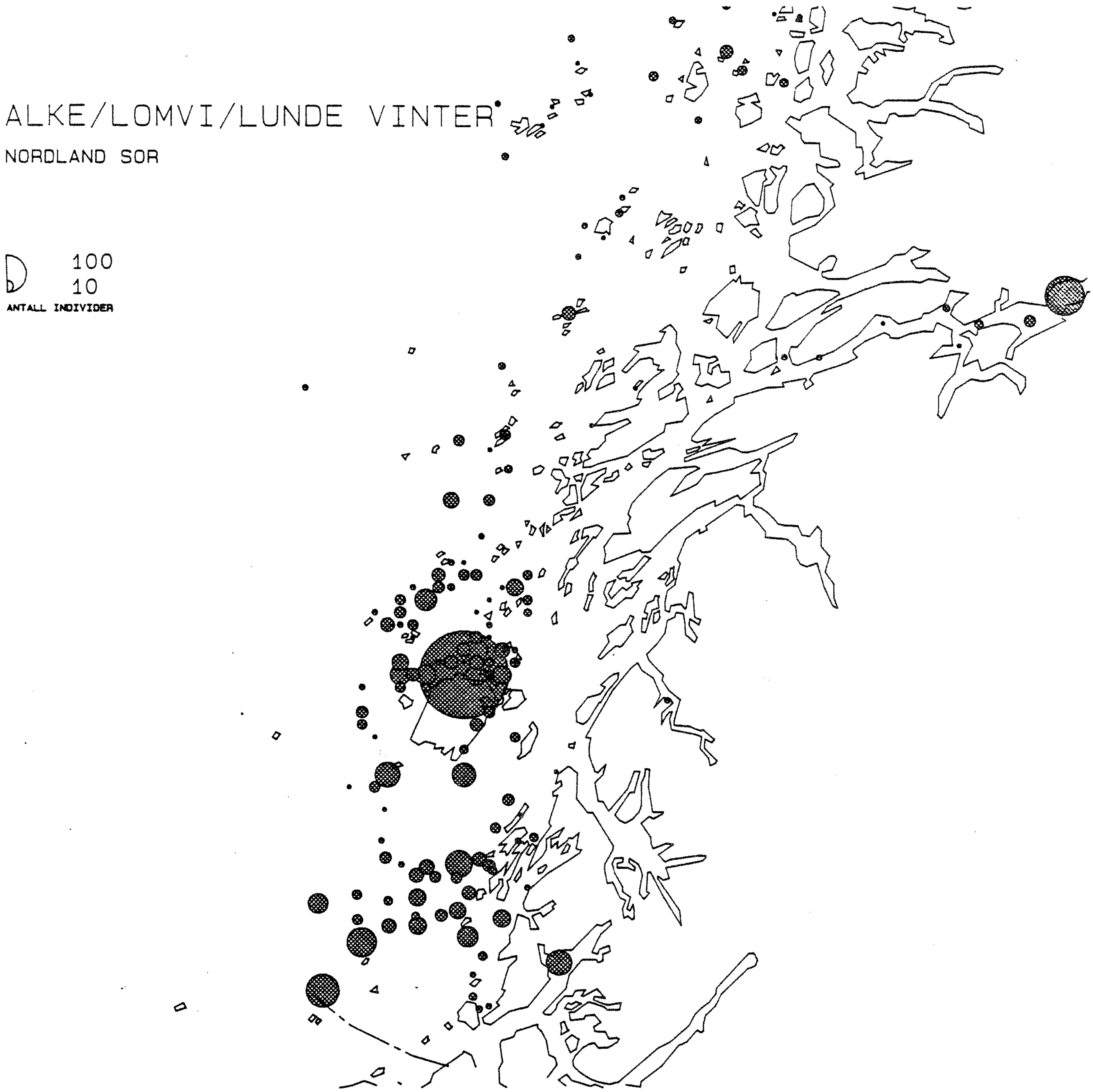


Fig. 2.62 Distribution of wintering Razorbills _Alca torda_, Guillemots _Uria aalge_ and Puffins _Fratercula arctica_ in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

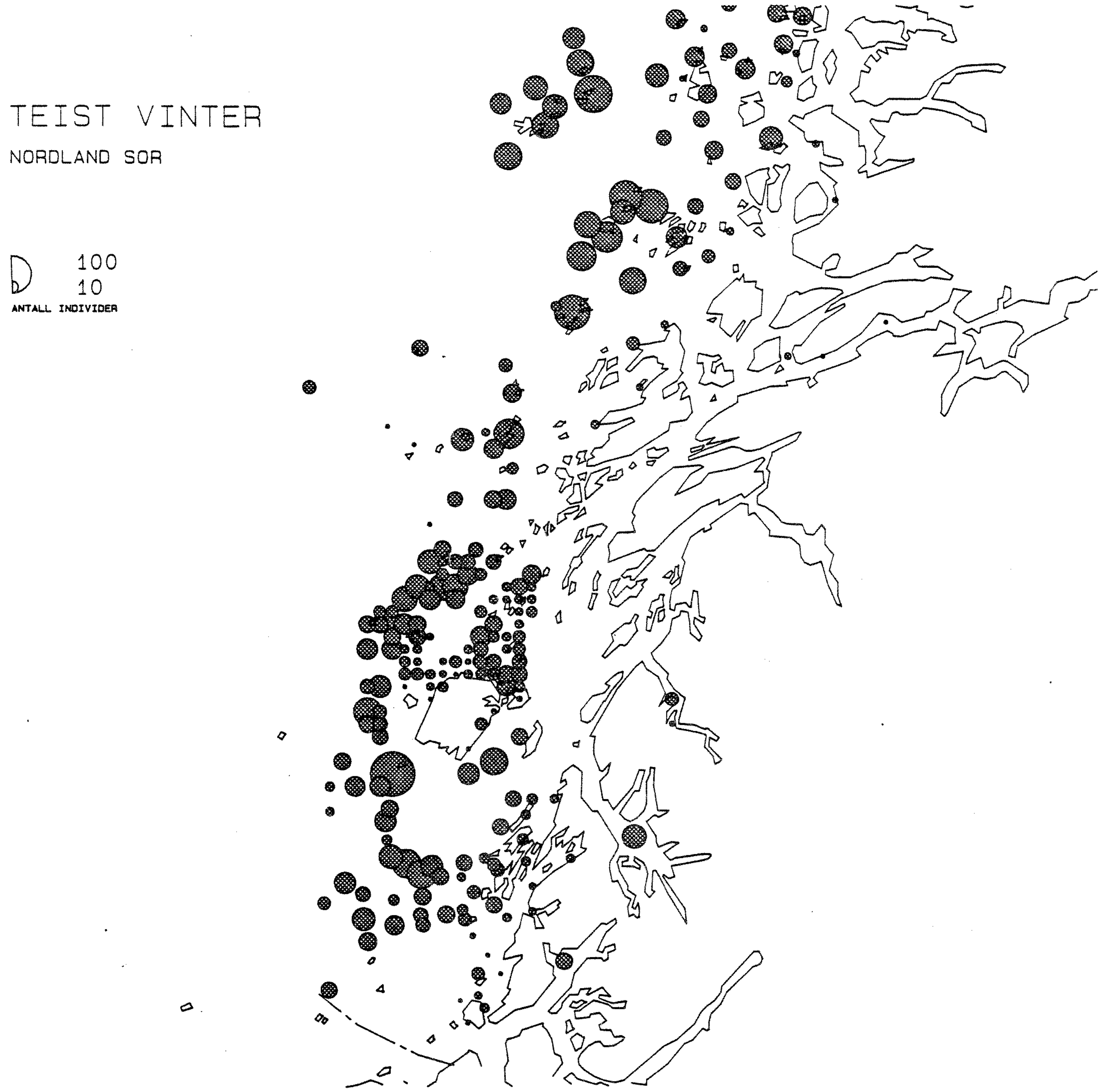


Fig. 2.63 Distribution of wintering Black Guillemots <u>Cepphus grylle</u> in Nordland (south). Scale refers to circle diameter and represents no. of individuals.

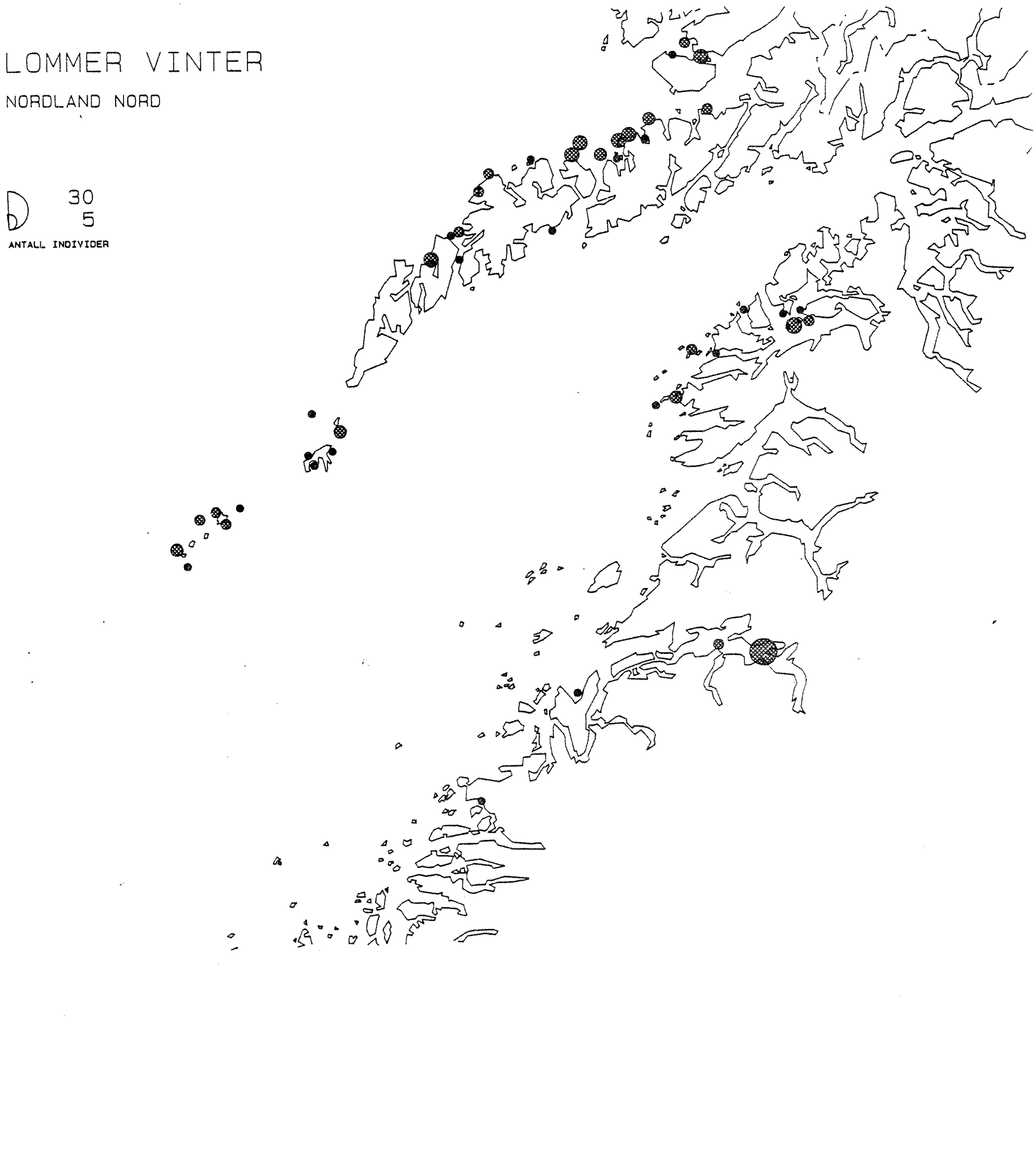


Fig. 2.64 Distribution of wintering Divers *Gavia sp.* in Nordland (north). Scale refers to circle diameter and represents no. of individuals.

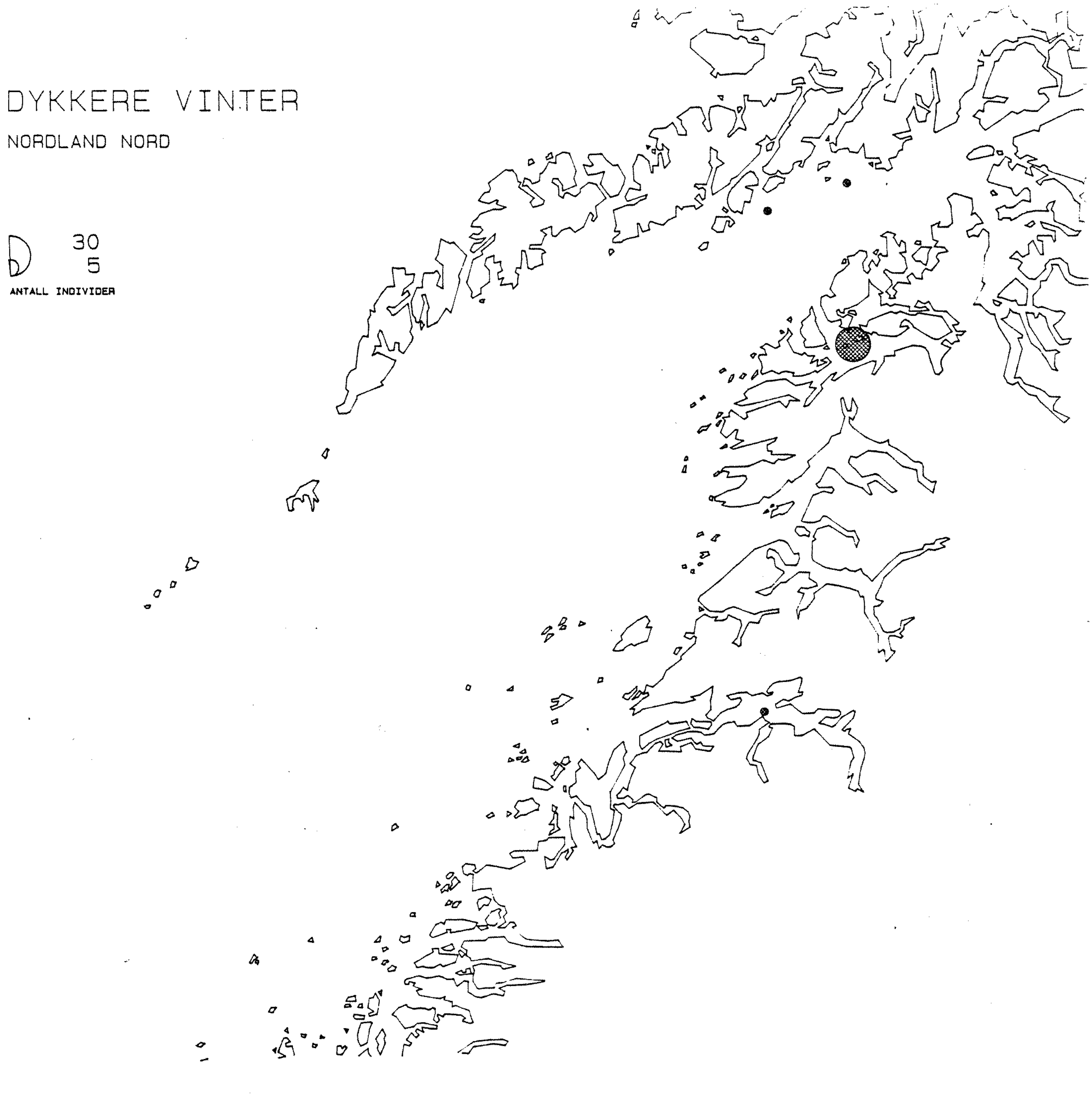


Fig. 2.65 Distribution of wintering Grebes Podiceps sp. in Nordland (north). Scale refers to circle diameter and represents no. of individuals.

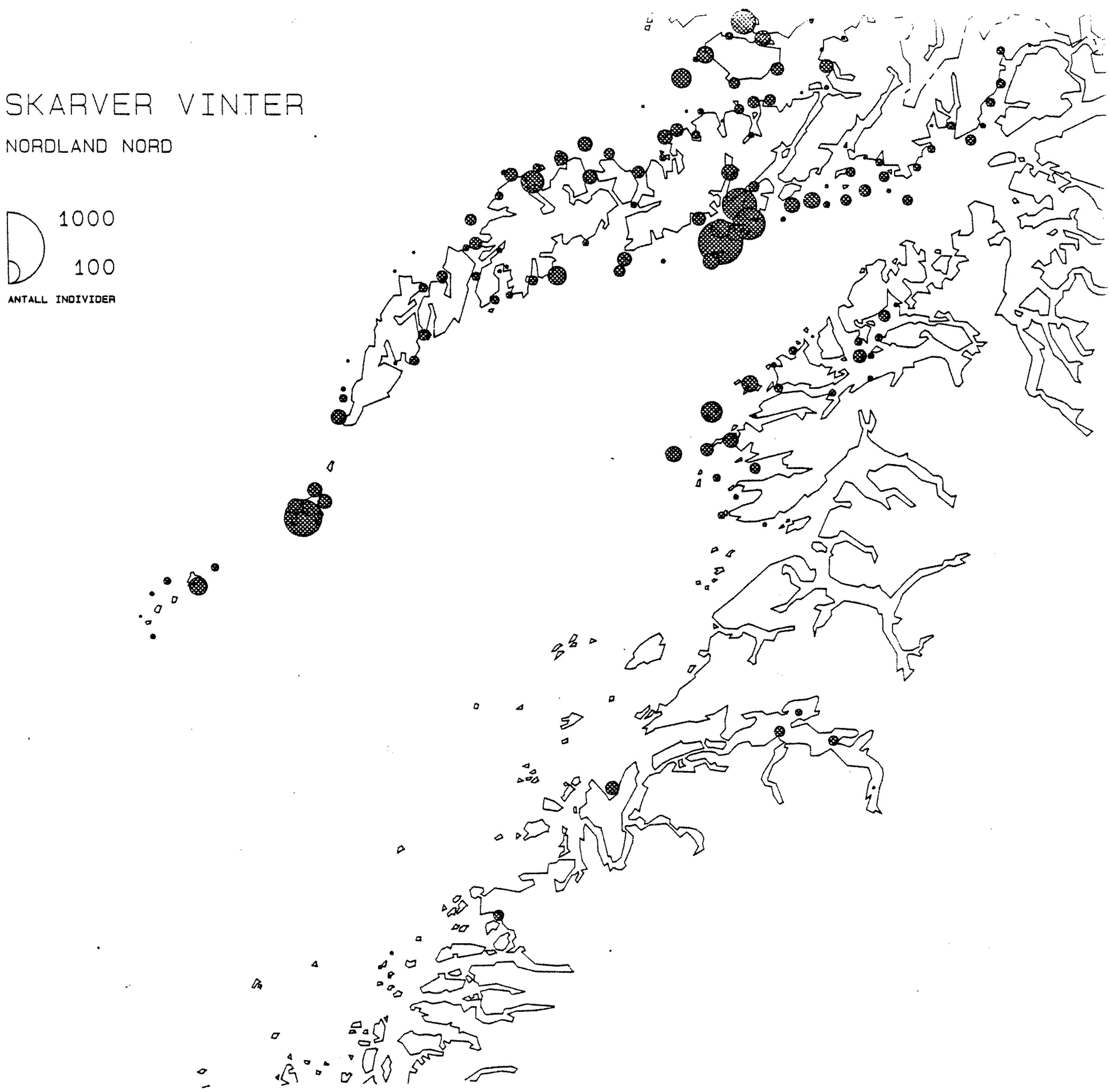


Fig. 2.66 Distribution of wintering Shags <u>Phalacrocorax sp.</u> in Nordland (north). Scale refers to circle diameter and represents no. of individuals.

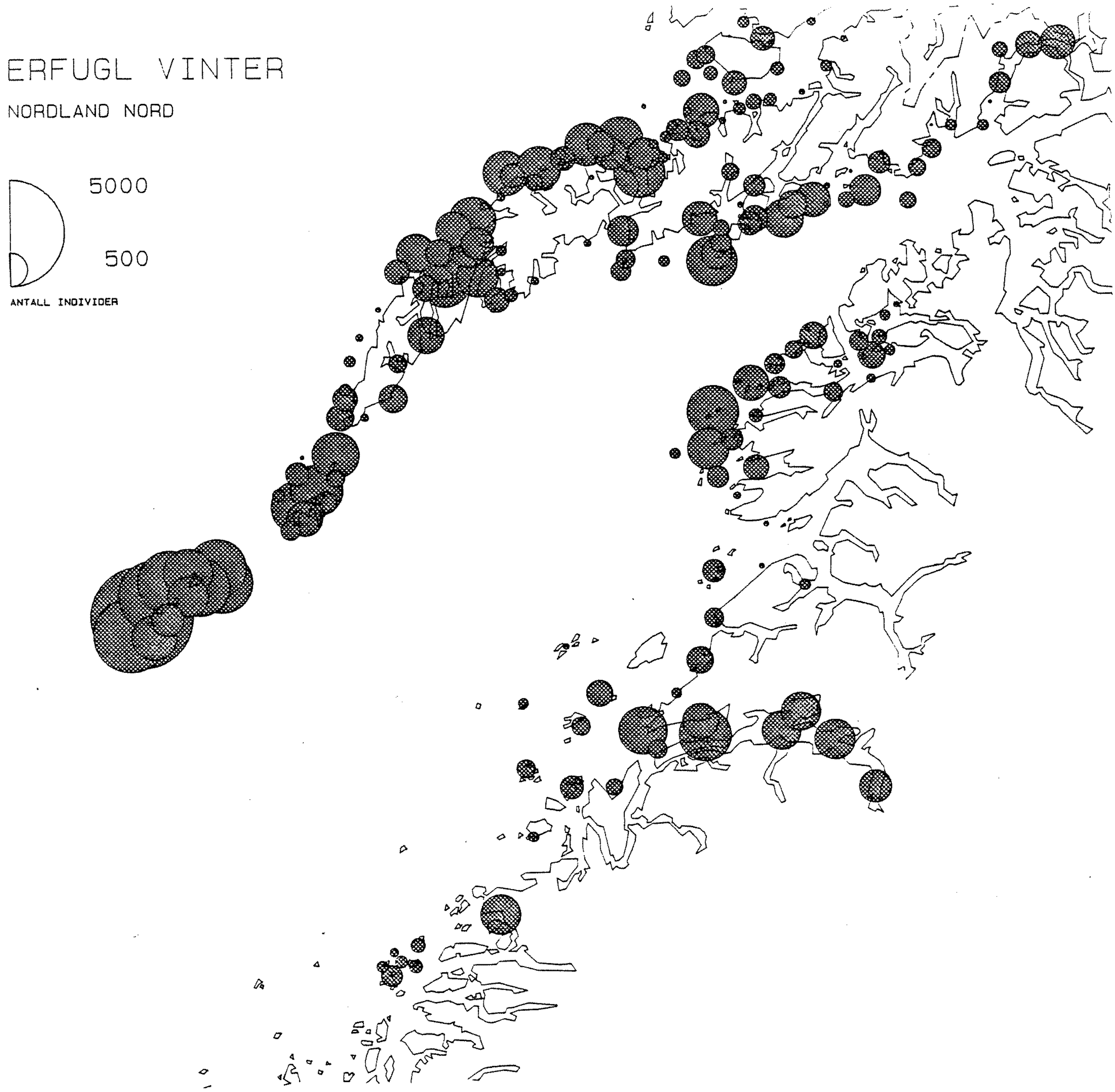


Fig. 2.67 Distribution of wintering Eiders <u>Somateria mollissima</u> in Nordland (north). Scale refers to circle diameter and represents no. of individuals.

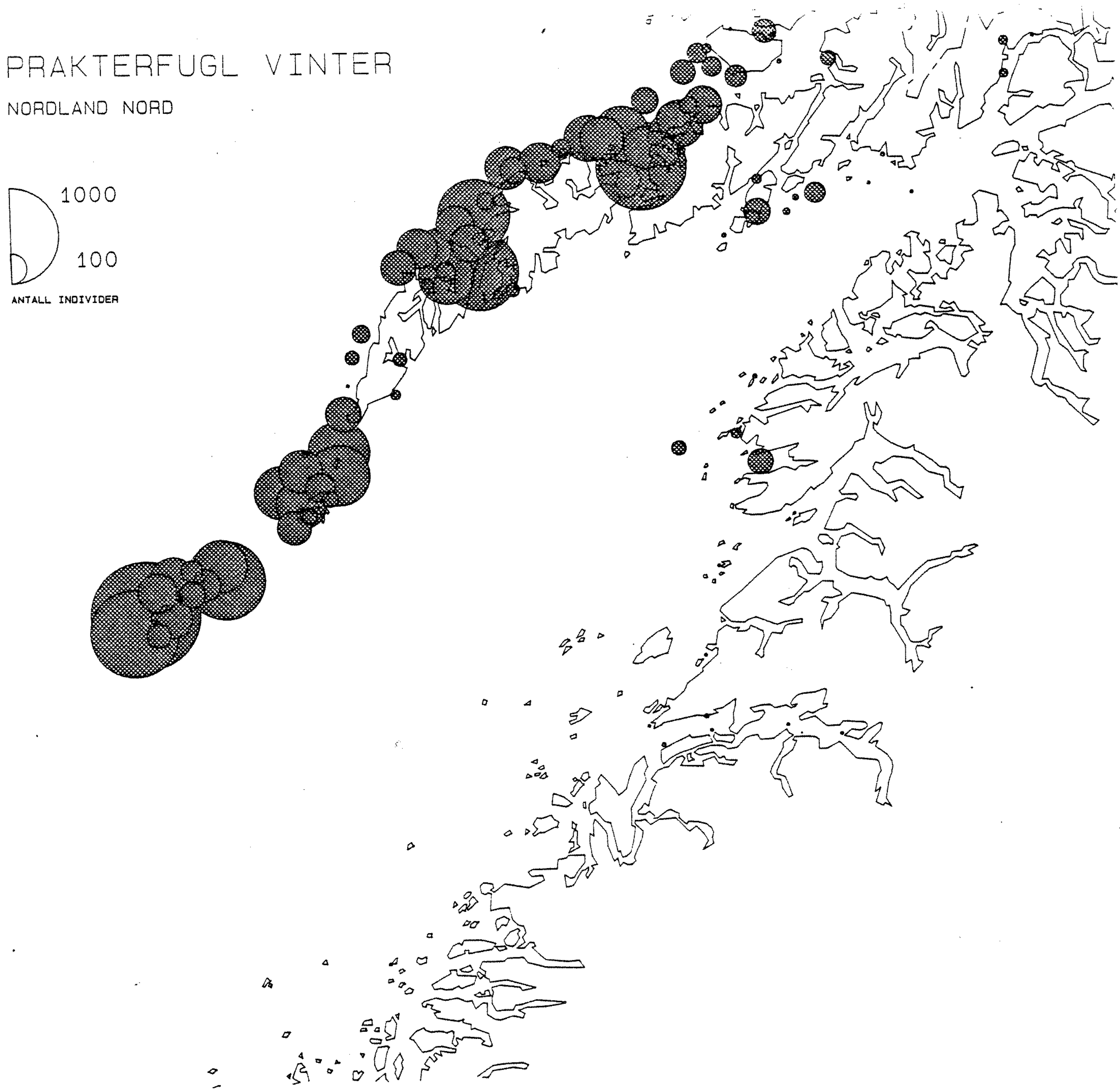


Fig. 2.68 Distribution of wintering King Eiders <u>Somateria spectabilis</u> in Nordland (north). Scale refers to circle diameter and represents no. of individuals.

Fig. 2.69 Distribution of wintering Velvet Scoters <u>Melanitta fusca</u> in Nordland (north). Scale refers to circle diameter and represents no. of individuals.

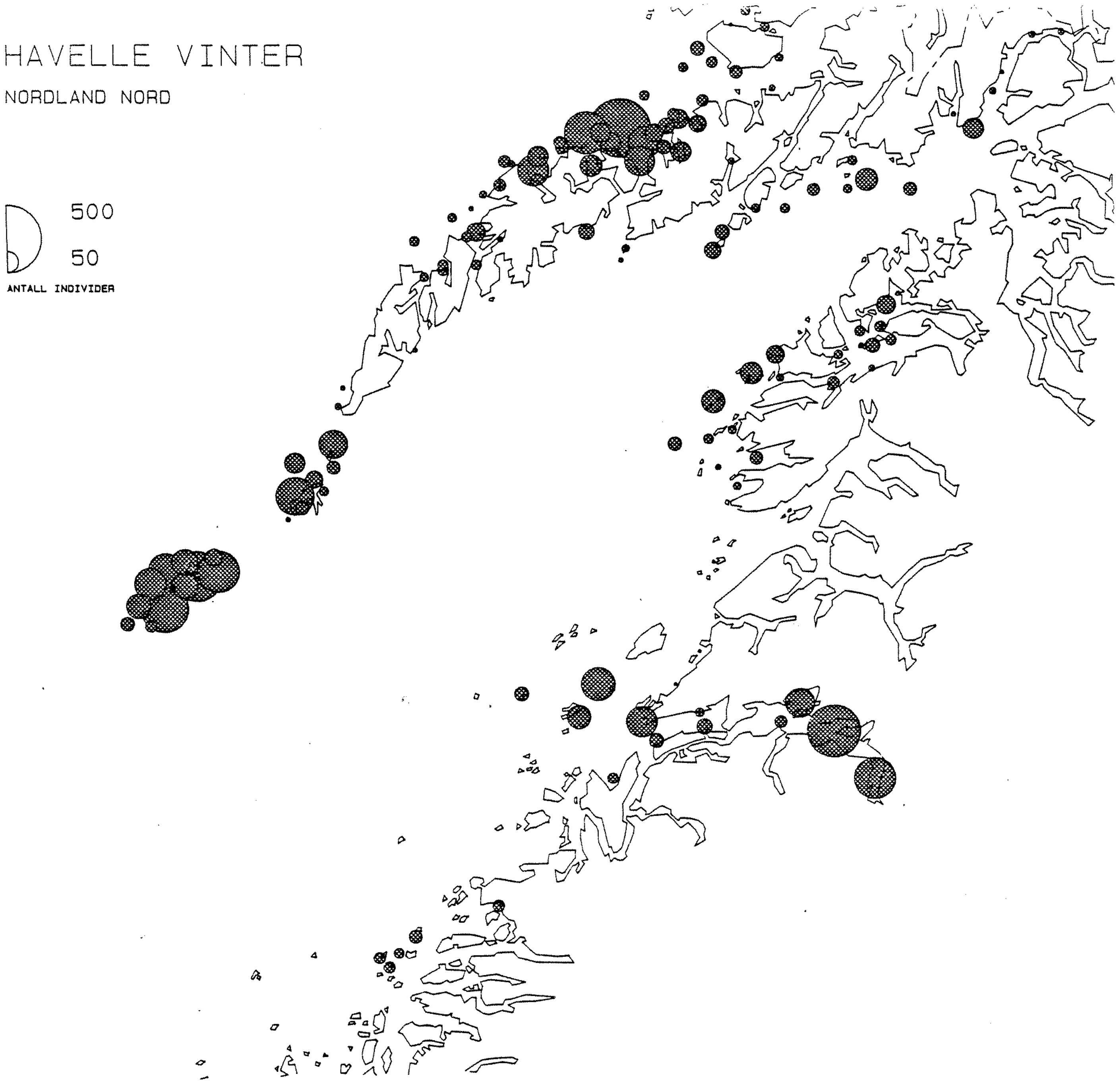


Fig. 2.70 Distribution of wintering Long-tailed Ducks <u>Clangula hyemalis</u> in Nordland (north). Scale refers to circle diameter and represents no. of individuals.

Fig. 2.71 Distribution of wintering Red-breasted Mergansers Mergus serrator in Nordland (north). Scale refers to circle diameter and represents no. of individuals.

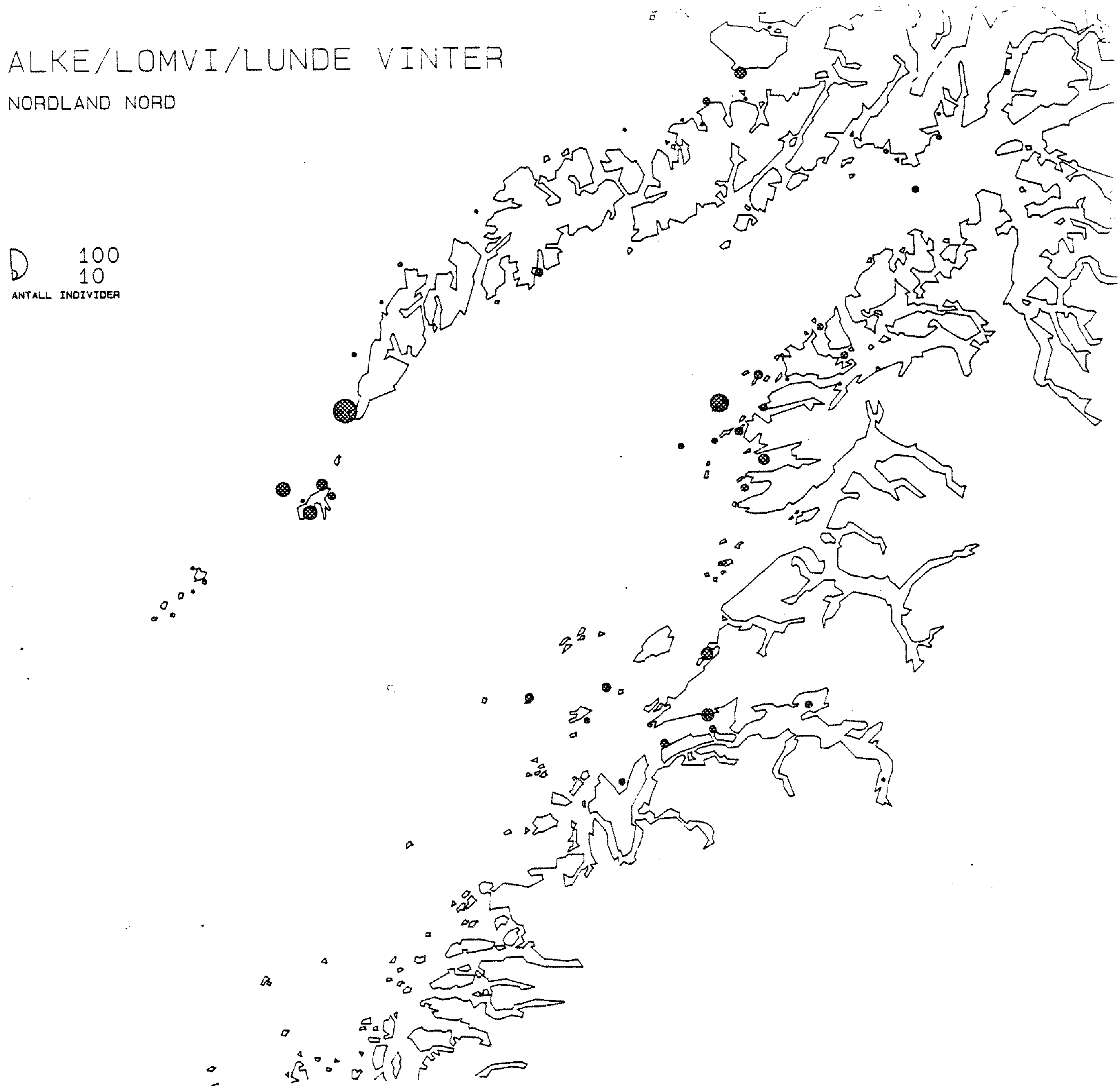


Fig. 2.72 Distribution of wintering Razorbills Alca torda, Guillemots Uria aalge and Puffins Fratercula arctica in Nordland (north). Scale refers to circle diameter and represents no. of individuals.

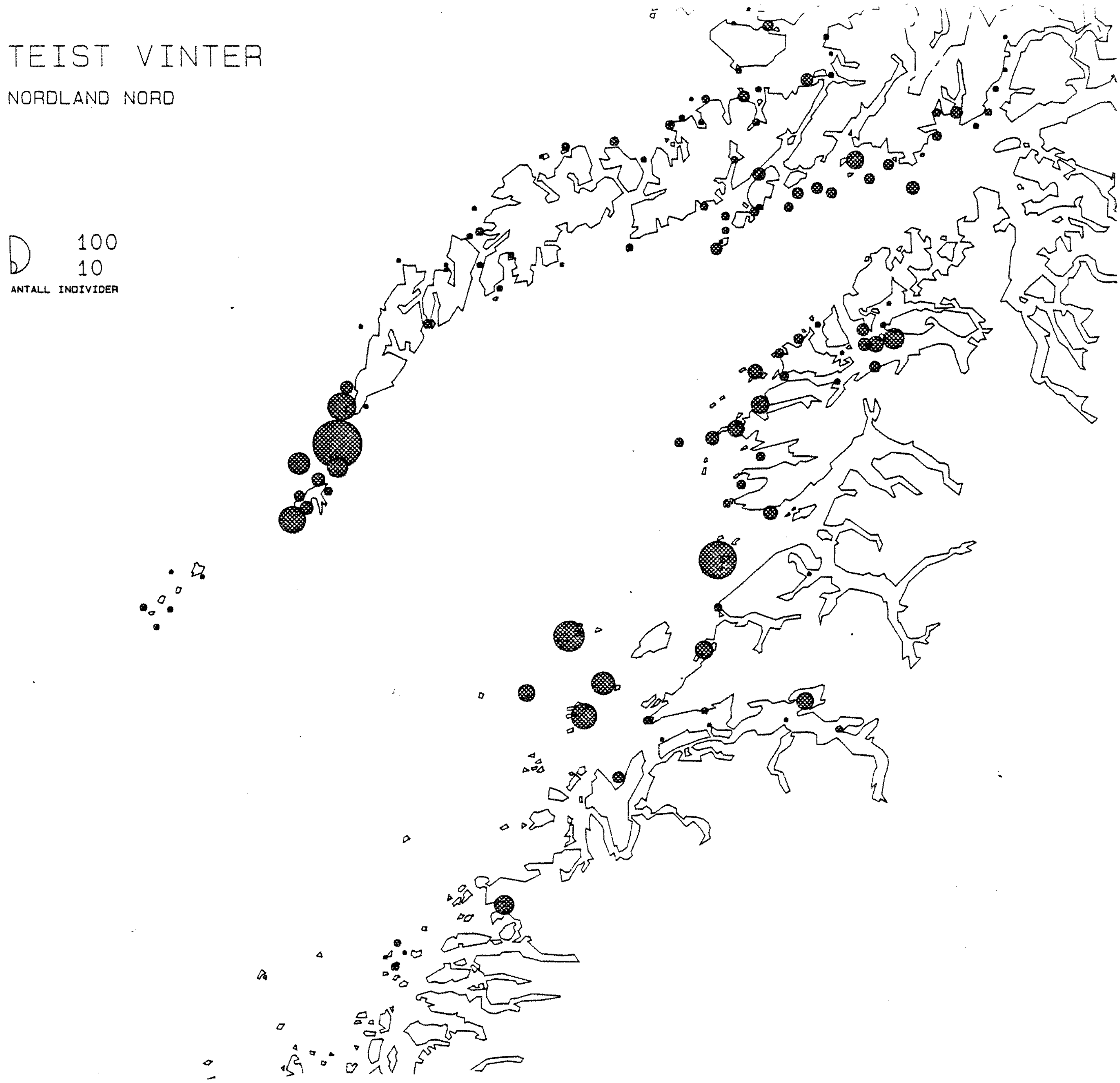


Fig. 2.73 Distribution of wintering Black Guillemots *Cepphus grylle* in Nordland (north). Scale refers to circle diameter and represents no. of individuals.

3. Seabirds at sea

	July-Aug. 1985	8.-19.4. 1986	24.-30.4. 1986
Fulmar	3. 1	3. 7	3.14
Gannet	3. 2	3. 8	3.15
Kittiwake	3. 3	3. 9	3.16
Razorbill	3. 4	3.10	3.17
Guillemot	3. 5	3.11	3.18
Puffin	3. 6	3.12	3.19
Little Auk		3.13	3.20

HAVHEST JULI-AUG. 1985

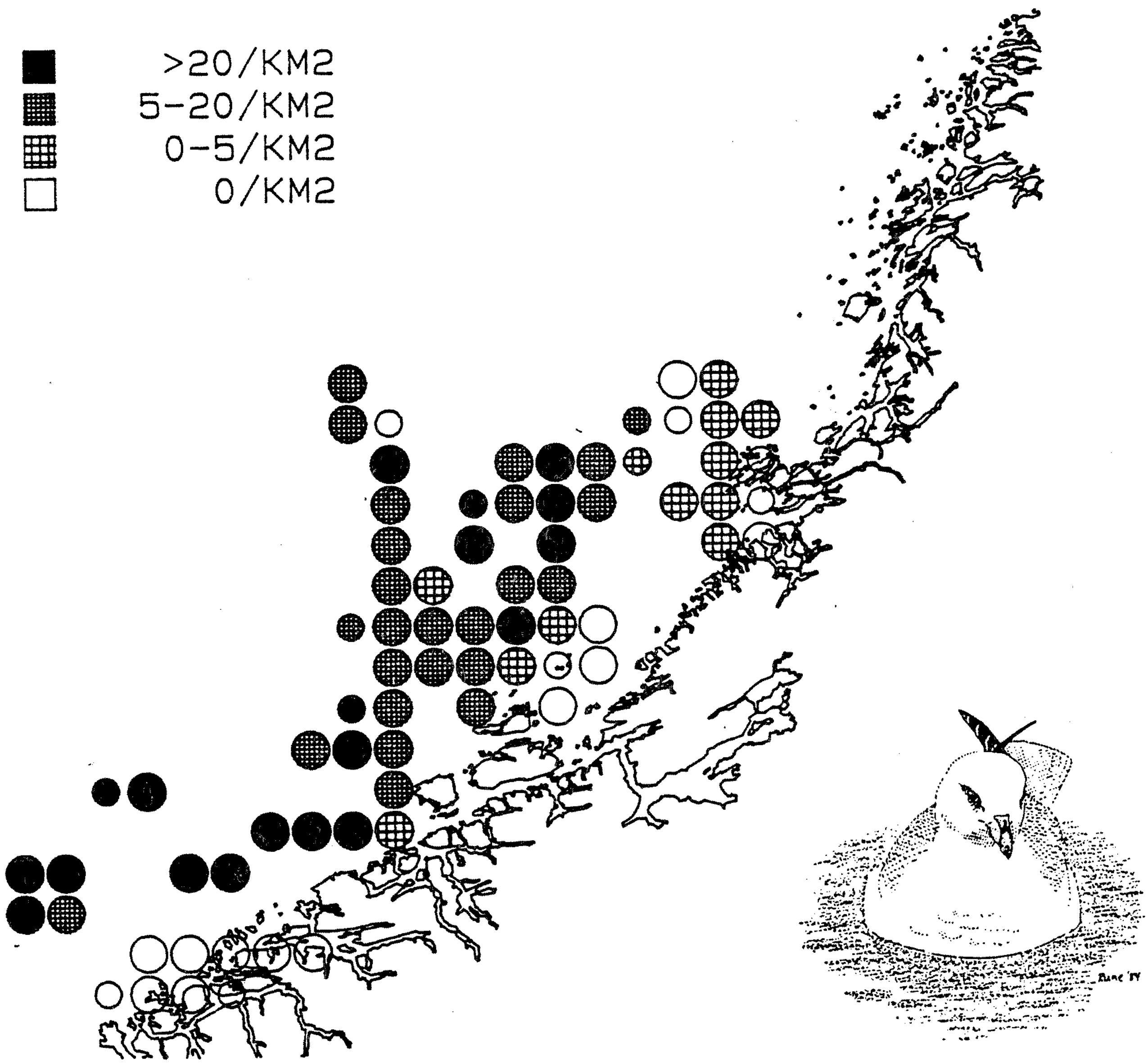


Fig. 3. 1 Density of Fulmars <u>Fulmar glacialis</u> at sea in July-aug. 1985. Small symbols show a survey distance of less than 6 km. In areas close to Runde and Ålesund Fulmars were not counted.

HAVSULE JULI-AUG. 1985

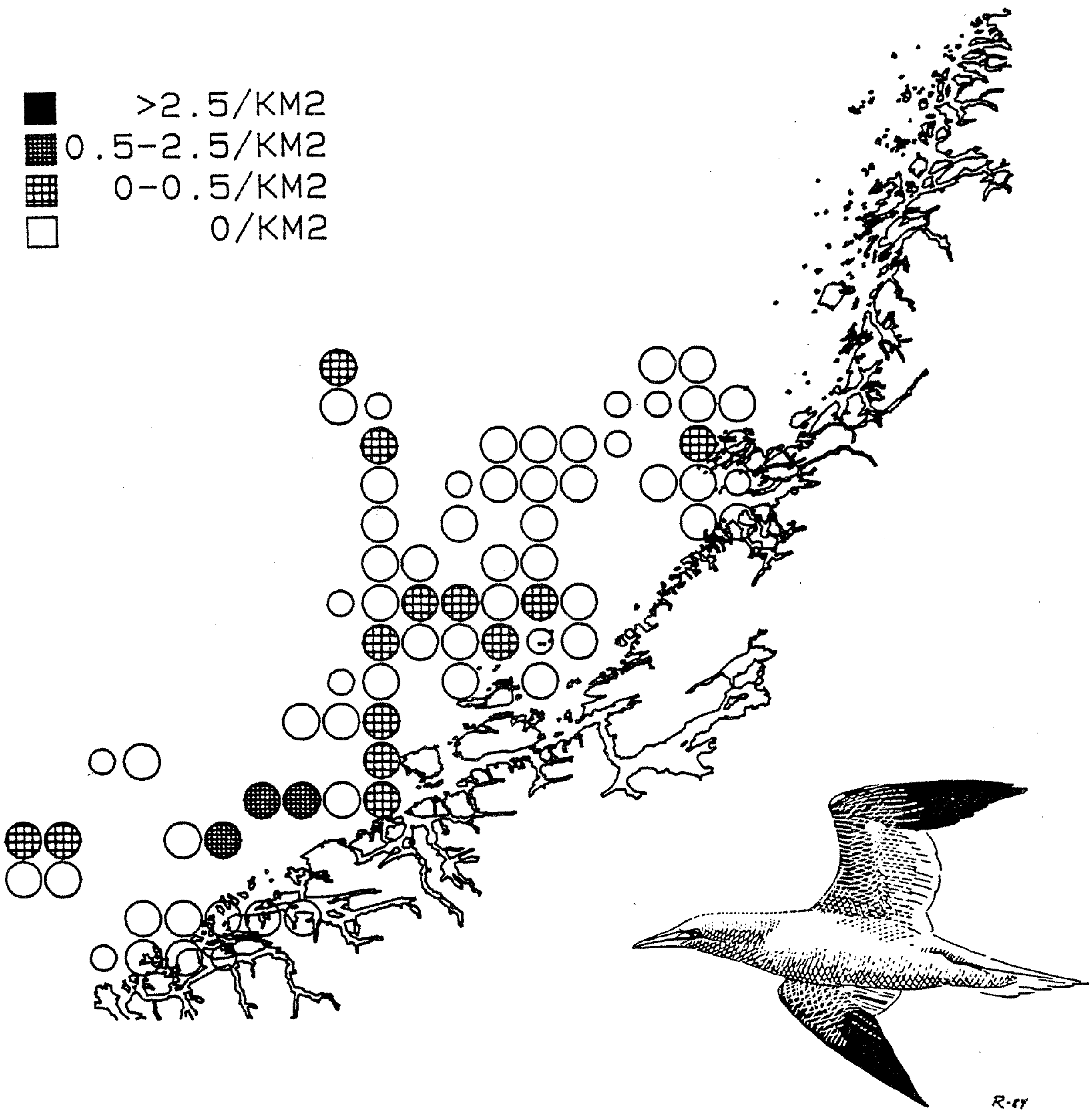


Fig. 3. 2 Density of Gannets <u>Sula bassana</u> at sea in July-aug. 1985. Small symbols show a survey distance of less than 6 km. In areas close to Runde and Ålesund Gannets were not counted.

KRYKKJE JULI-AUG. 1985

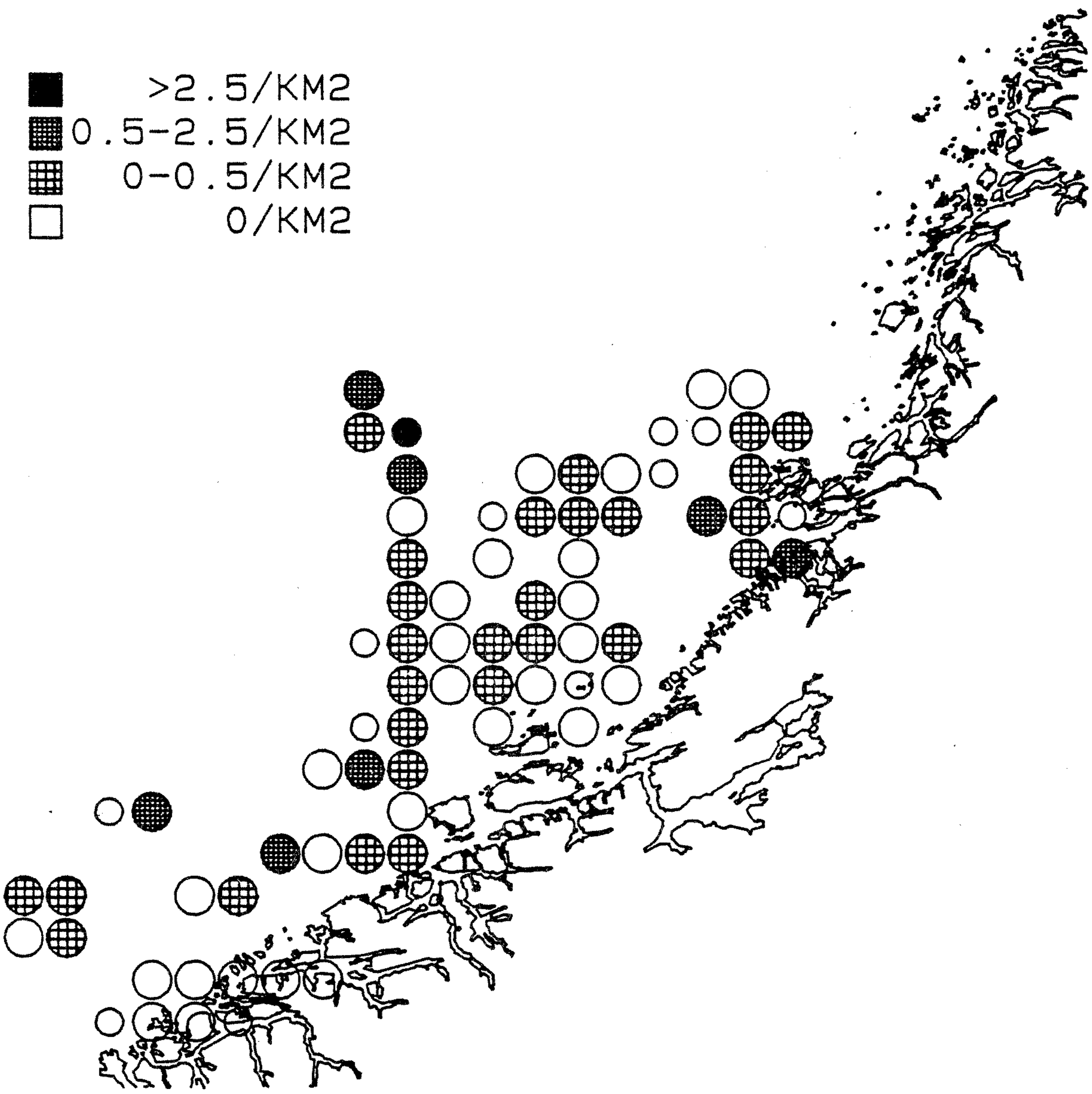


Fig. 3. 3 Density of Kittiwakes <u>Rissa tridactyla</u> at sea in July-aug. 1985. Small symbols show a survey distance of less than 6 km. In some areas Kittiwakes were not counted.

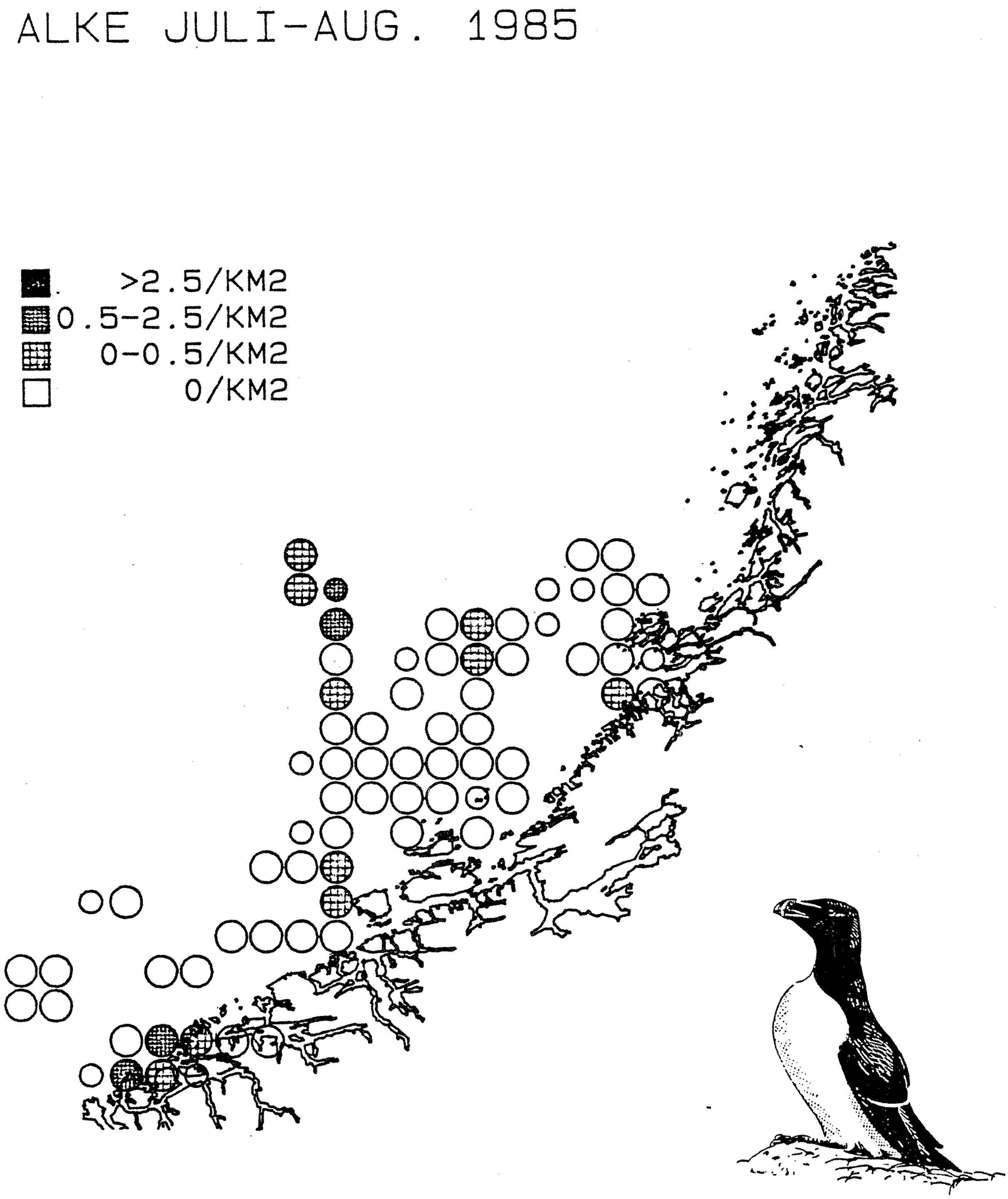


Fig. 3. 4. Density of Razorbills <u>Alca torda</u> at sea in July-aug. 1985. Small symbols show a survey distance of less than 6 km.

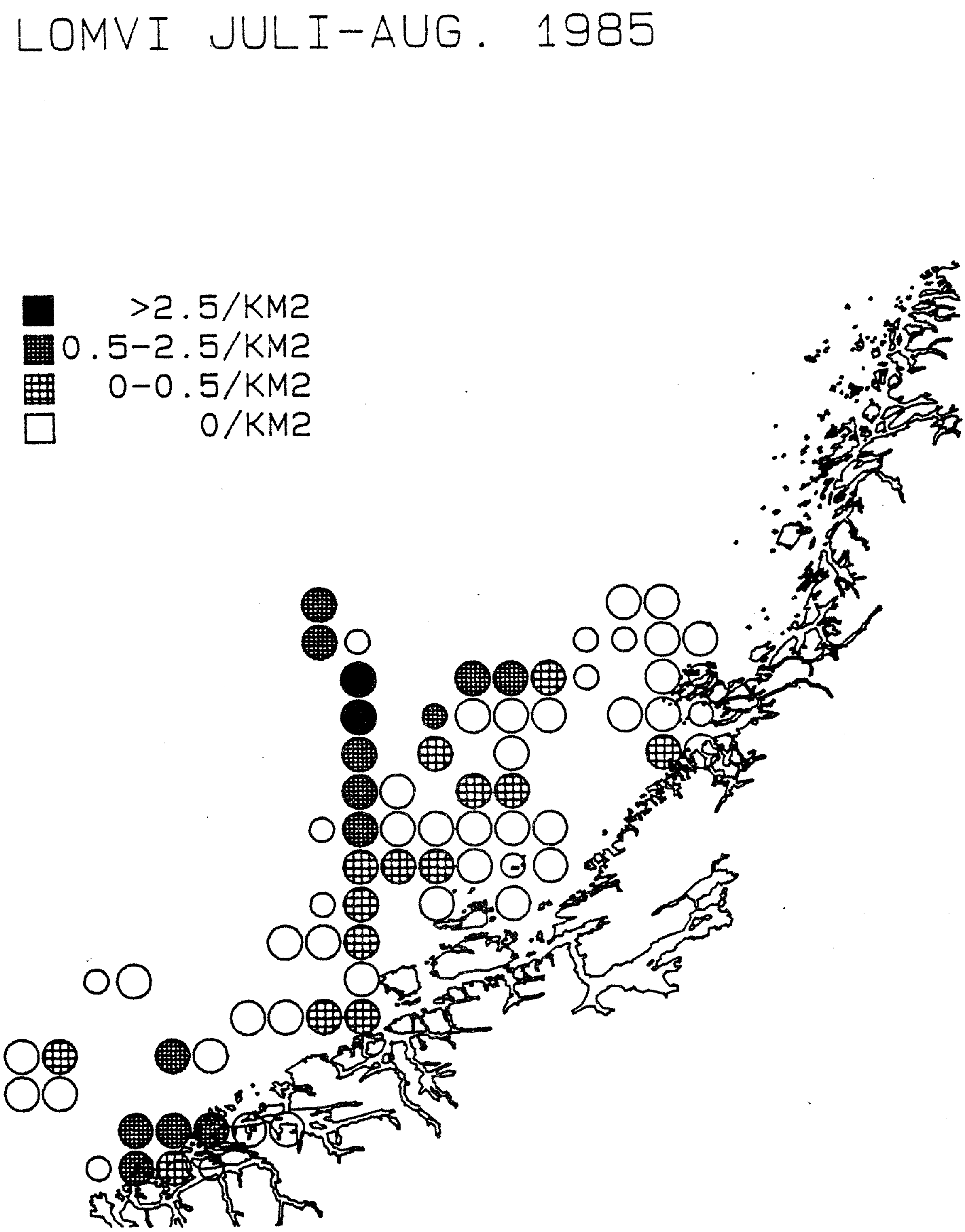


Fig. 3. 5 Density of Guillemots <u>Uria aalge</u> at sea in July-aug. 1985. Small symbols show a survey distance of less than 6 km.

LUNDE JULI-AUG. 1985

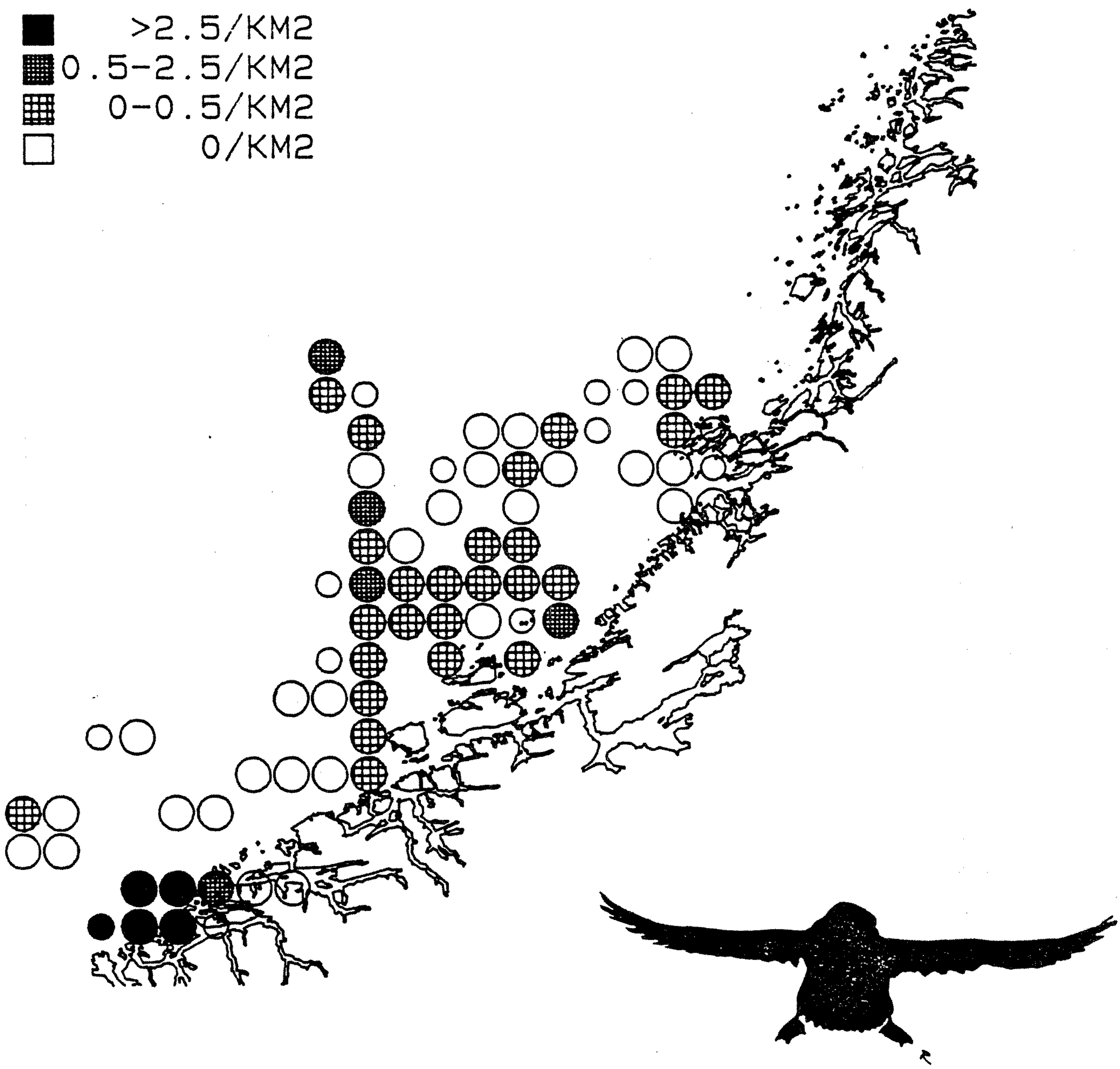


Fig. 3. 6 Density of Puffins <u>Fratercula arctica</u> at sea in July-aug. 1985. Small symbols show a survey distance of less than 6 km.

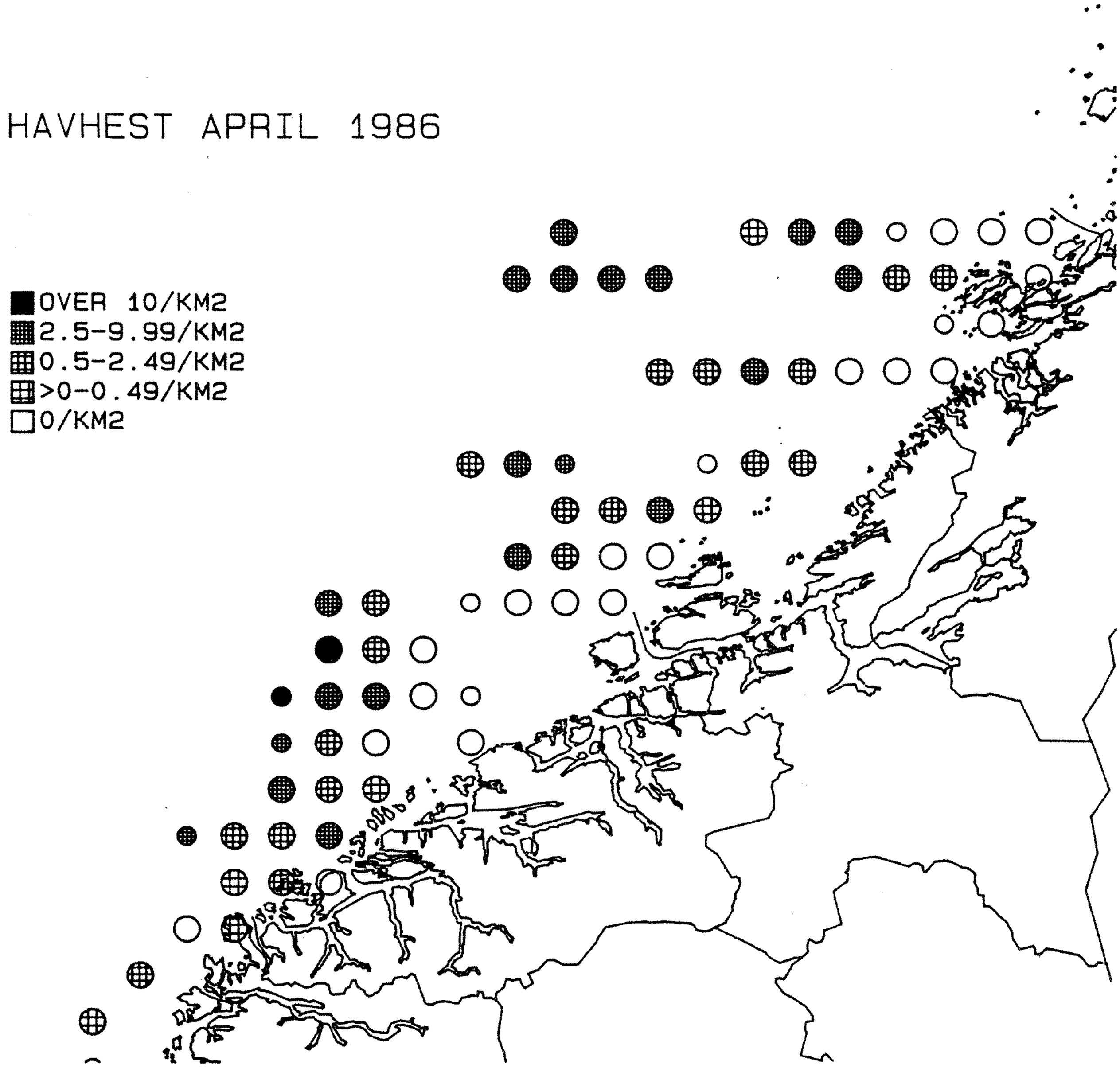


Fig. 3. 7 Density of Fulmars <u>Fulmar glacialis</u> at sea 8.-19.4. 1986. Small symbols show a survey distance of less than 6 km.

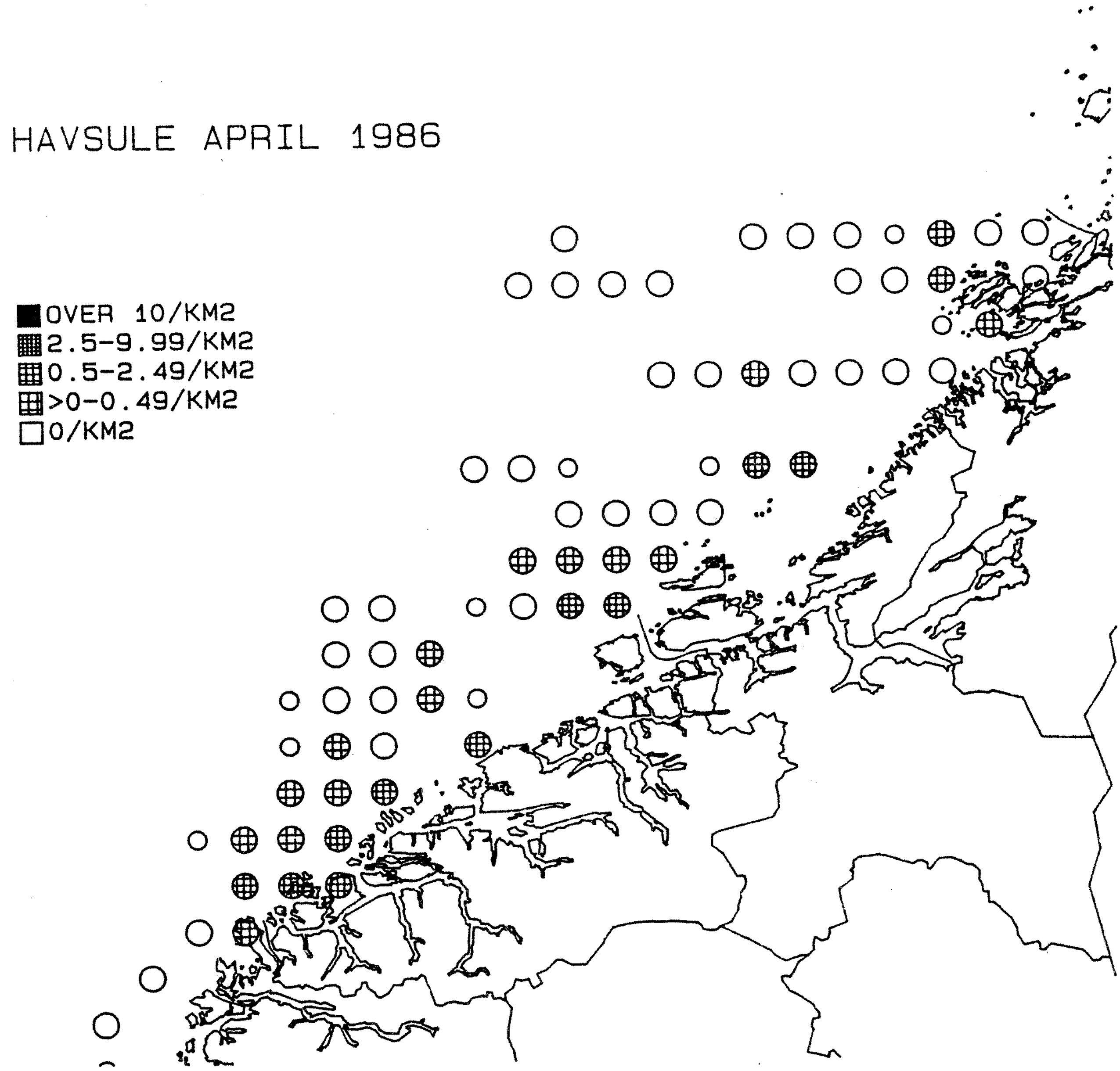


Fig. 3. 8 Density of Gannets <u>Sula bassana</u> at sea 8.-19.4.1986.
Small symbols show a survey distance of less than 6 km.

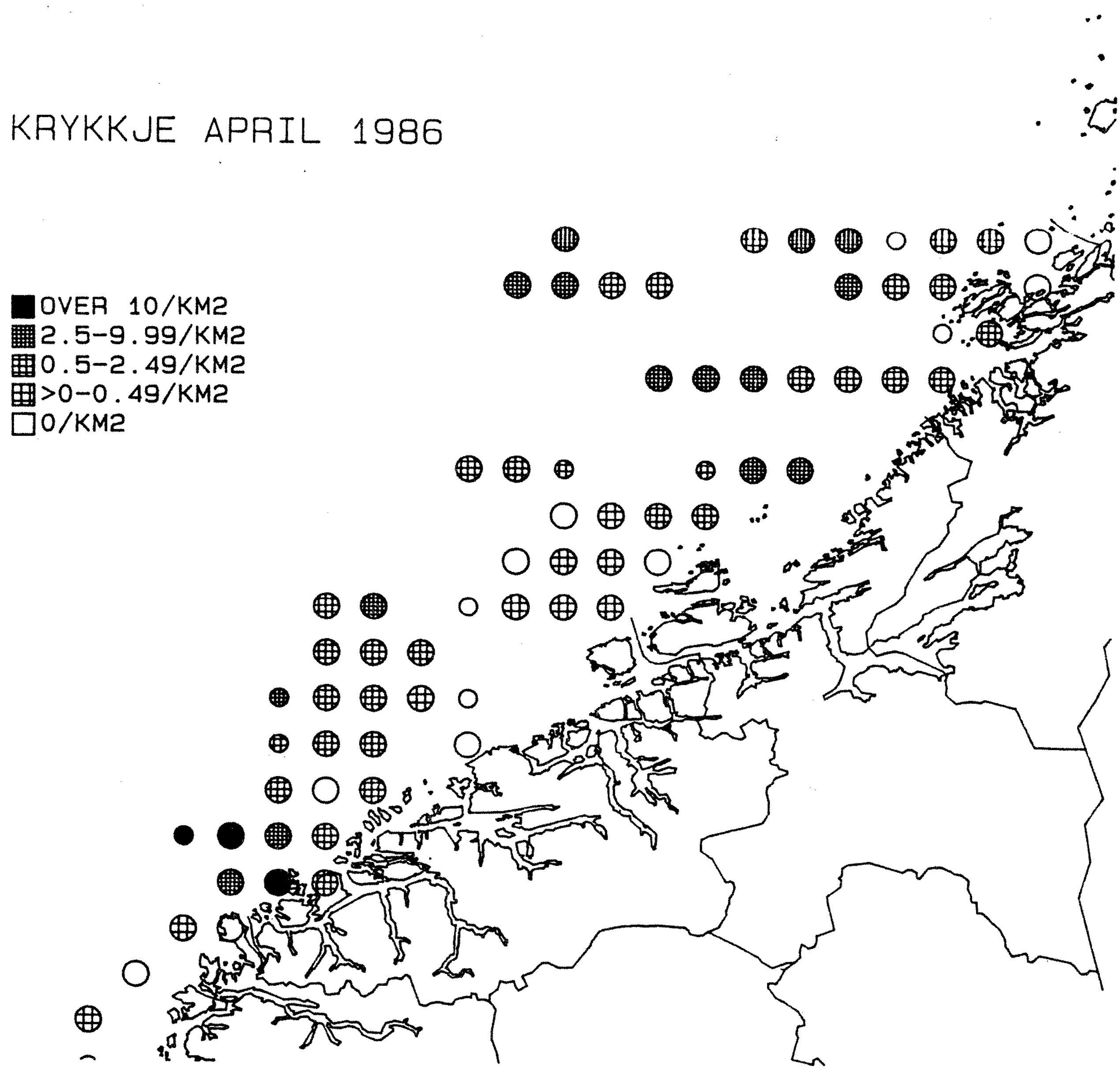


Fig. 3. 9 Density of Kittiwakes Rissa tridactyla at sea 8.-19.4. 1986. Small symbols show a survey distance of less than 6 km.

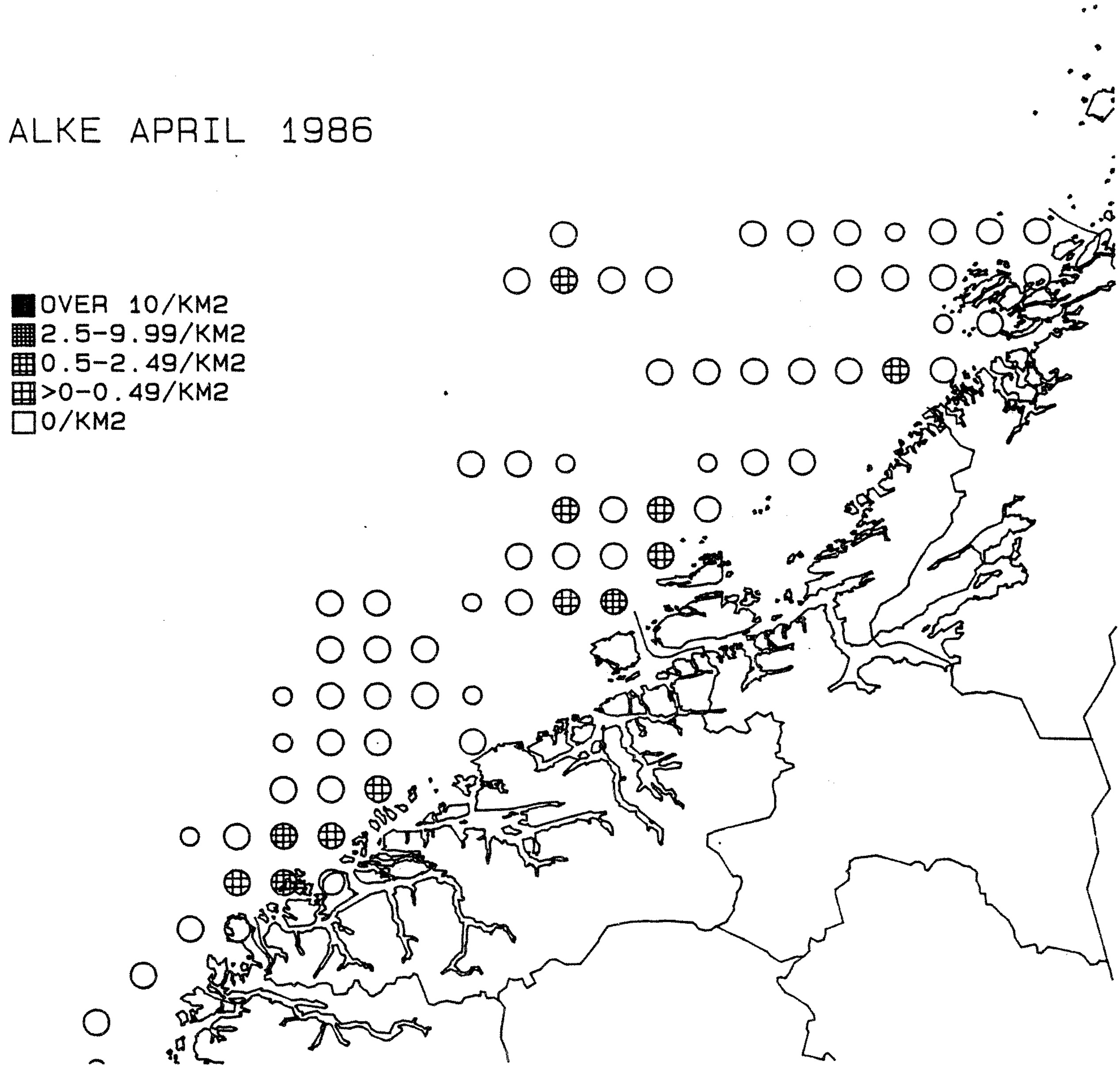


Fig. 3.10 Density of Razorbills Alca torda at sea 8.-19.4.1986. Small symbols show a survey distance of less than 6 km.

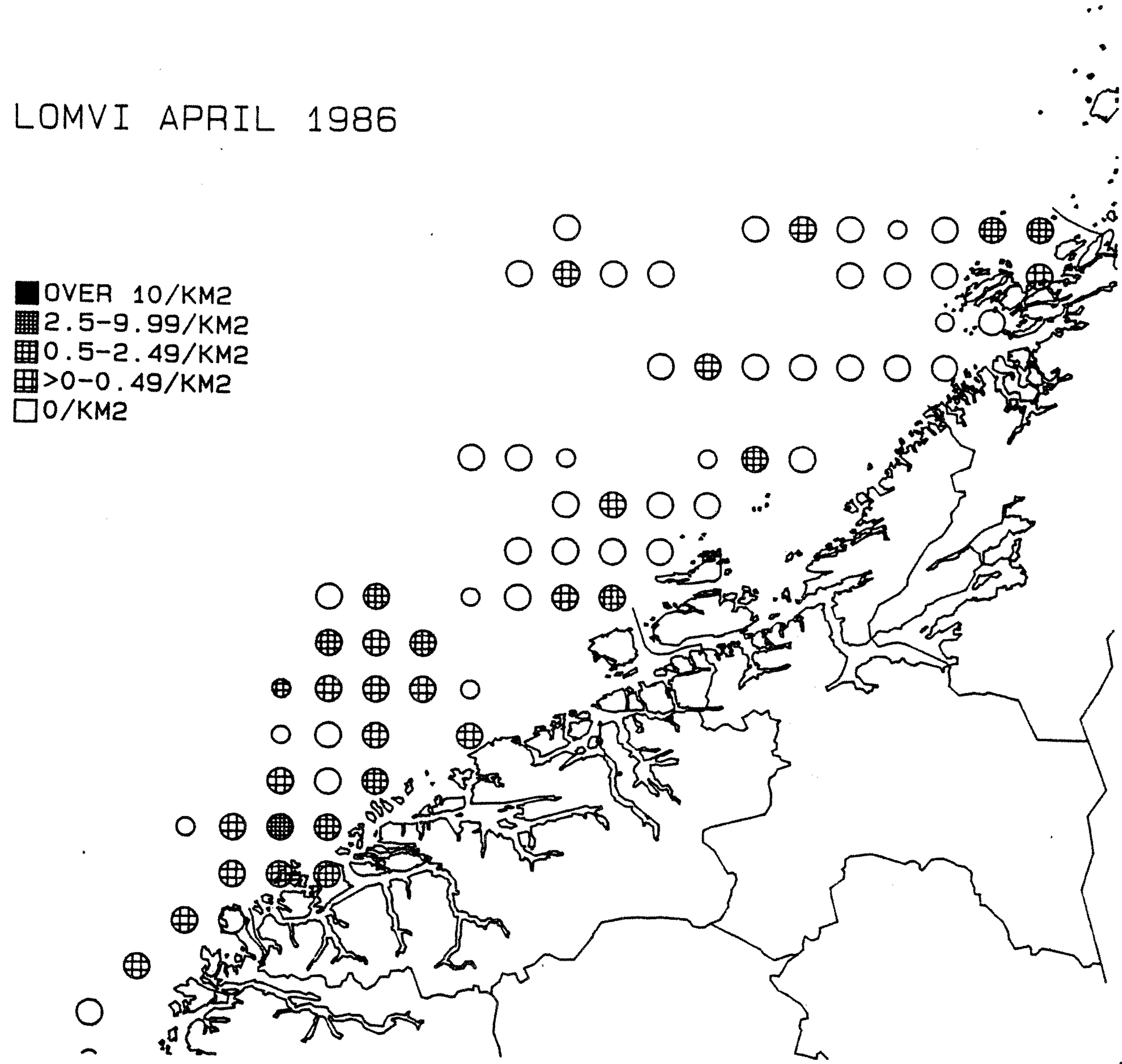


Fig. 3.11 Density of Guillemots <u>Uria aalge</u> at sea 8.-19.4.1986. Small symbols show a survey distance of less than 6 km.

6 km.

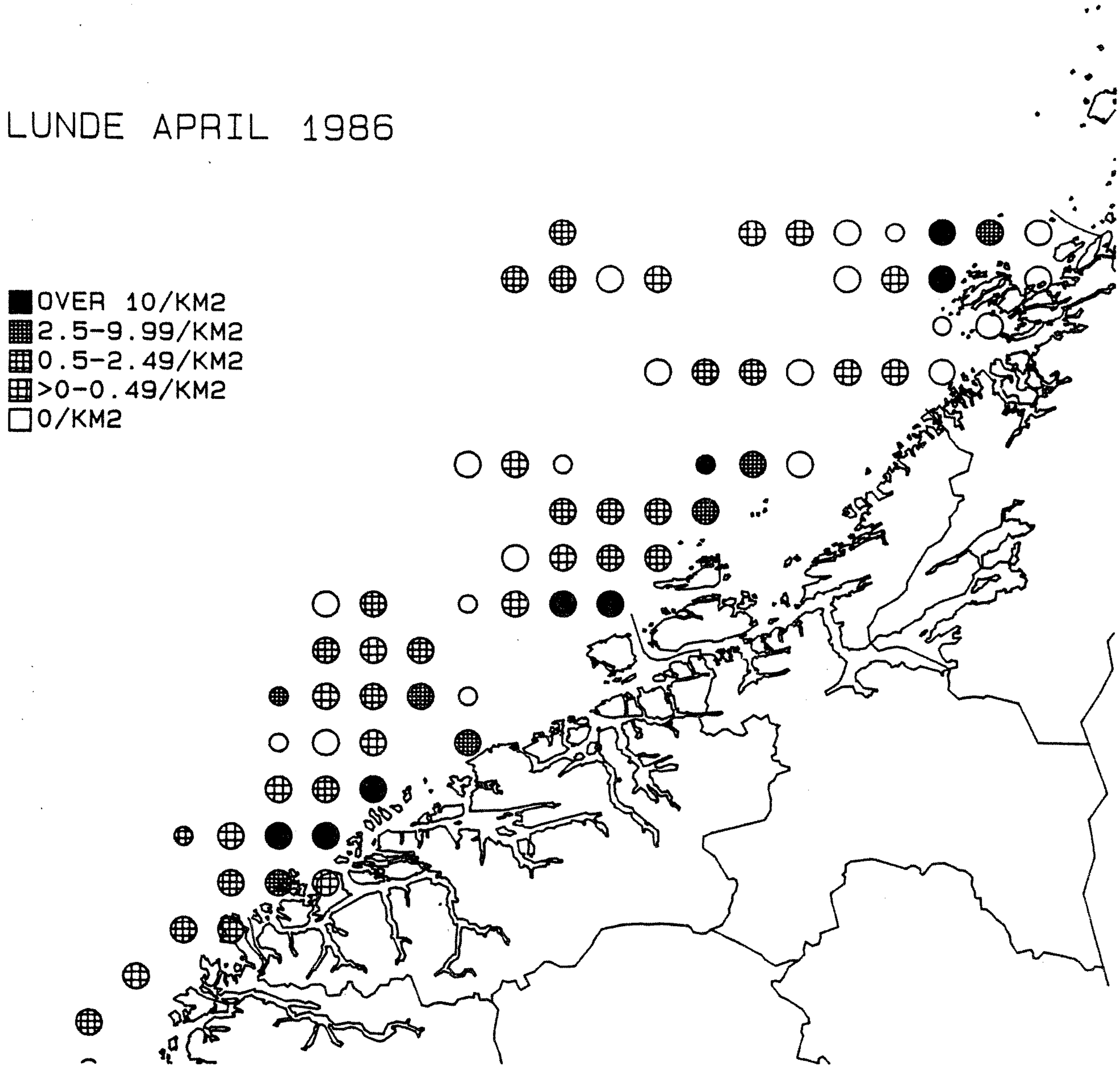


Fig. 3.12 Density of Puffins <u>Fratercula arctica</u> at sea 8.-19.4. 1986. Small symbols show a survey distance of less than 6 km.

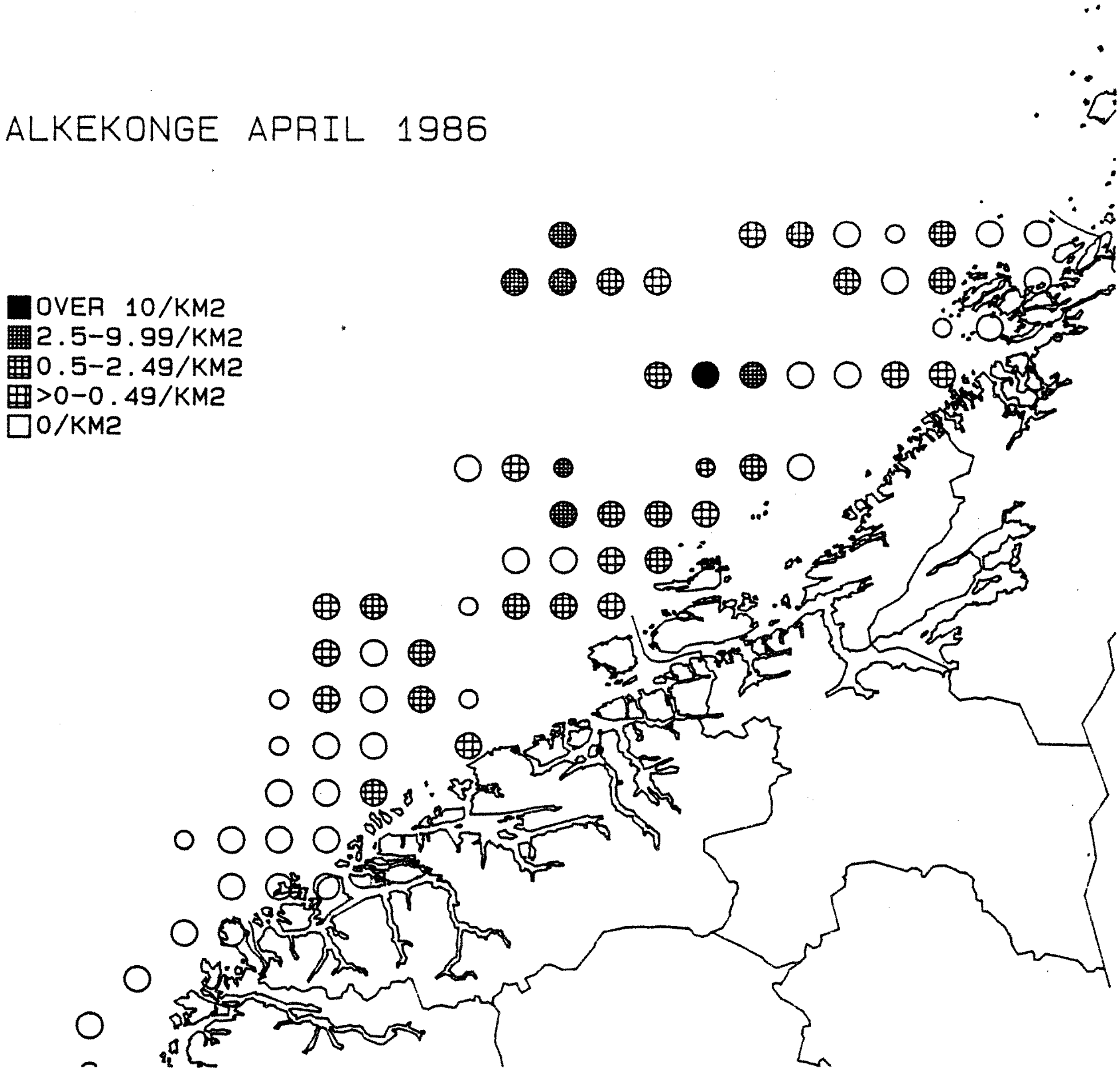


Fig. 3.13 Density of Little Auk *Alle alle* at sea 8.-19.4.1986. Small symbols show a survey distance of less than 6 km.

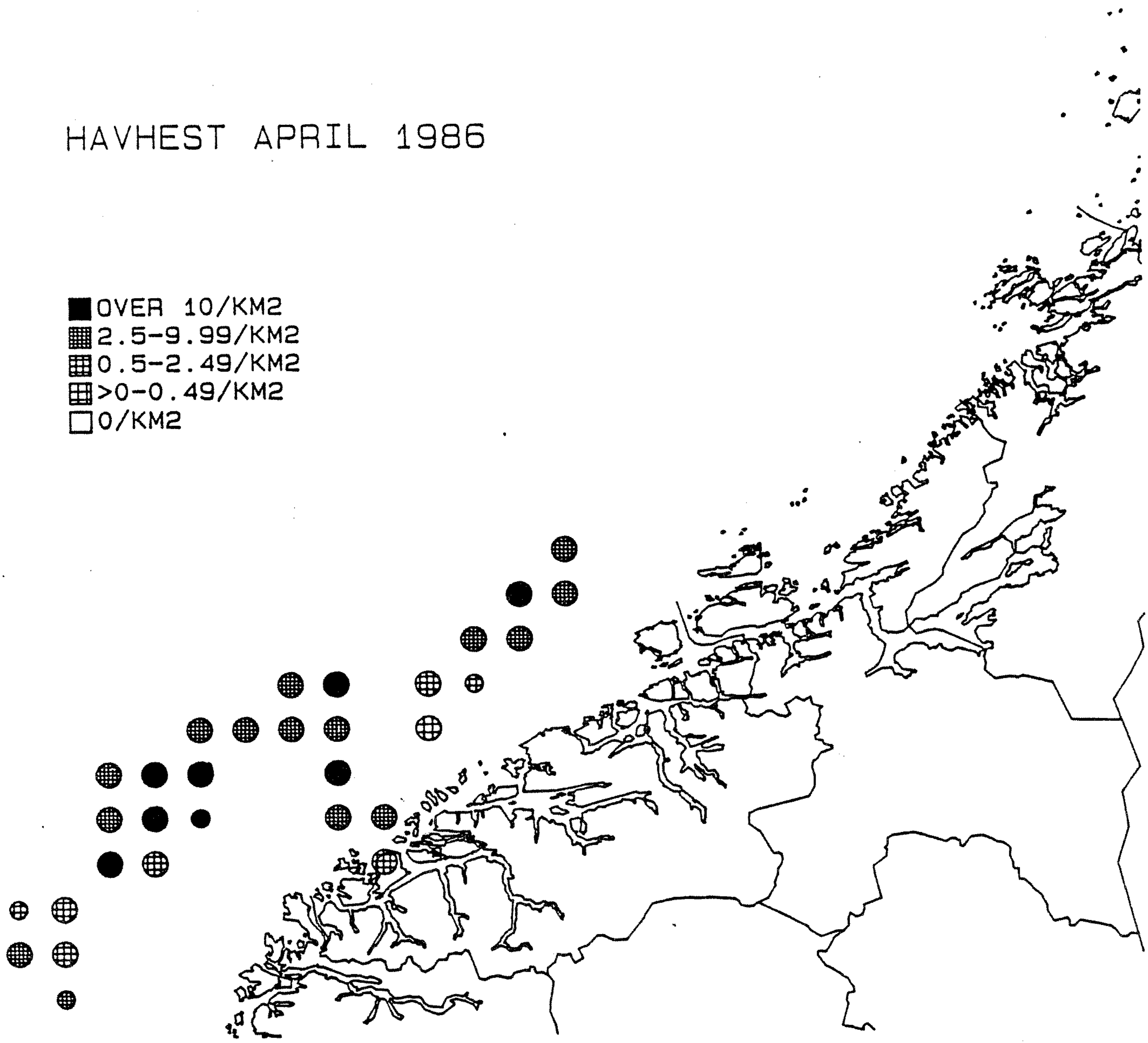


Fig. 3.14. Density of Fulmars <u>Fulmar glacialis</u> at sea 24.-30.4. 1986. Small symbols show a survey distance of less than 6 km.

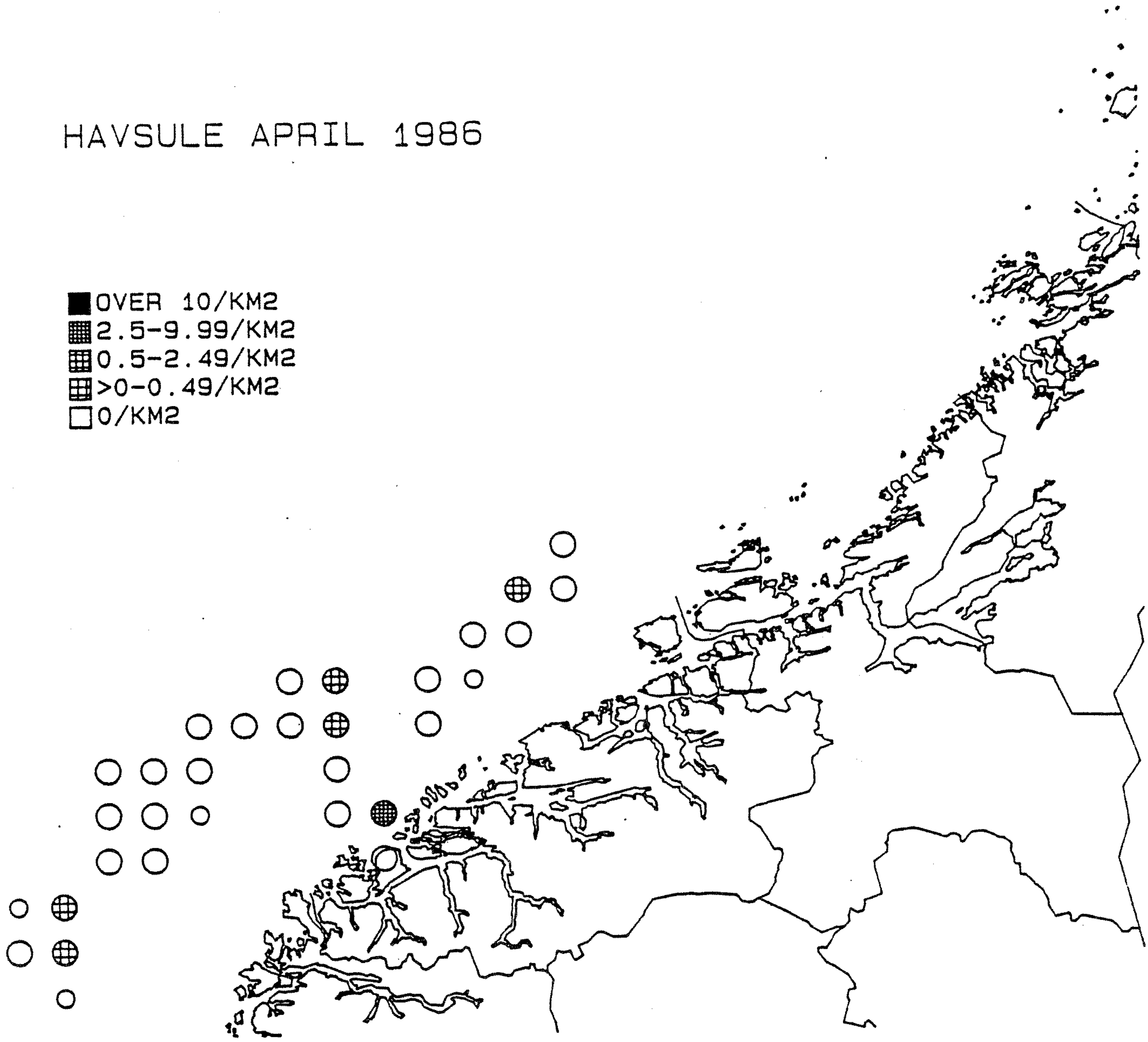


Fig. 3.15. Density of Gannets <u>Sula bassana</u> at sea 24.-30.4.1986. Small symbols show a survey distance of less than 6 km.

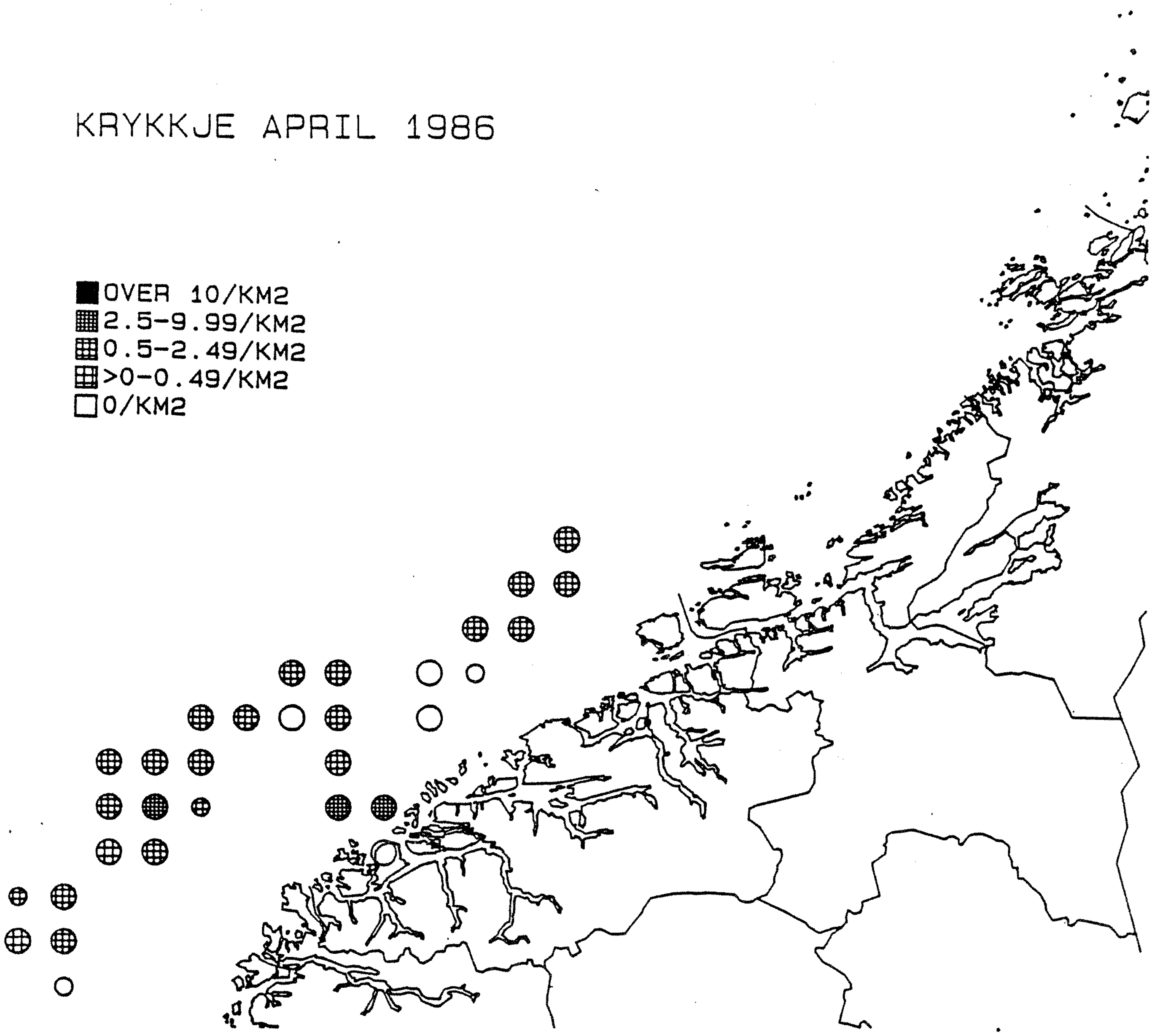


Fig. 3.16. Density of Kittiwakes <u>Rissa tridactyla</u> at sea 24.-30.4. 1986. Small symbols show a survey distance of less than 6 km.

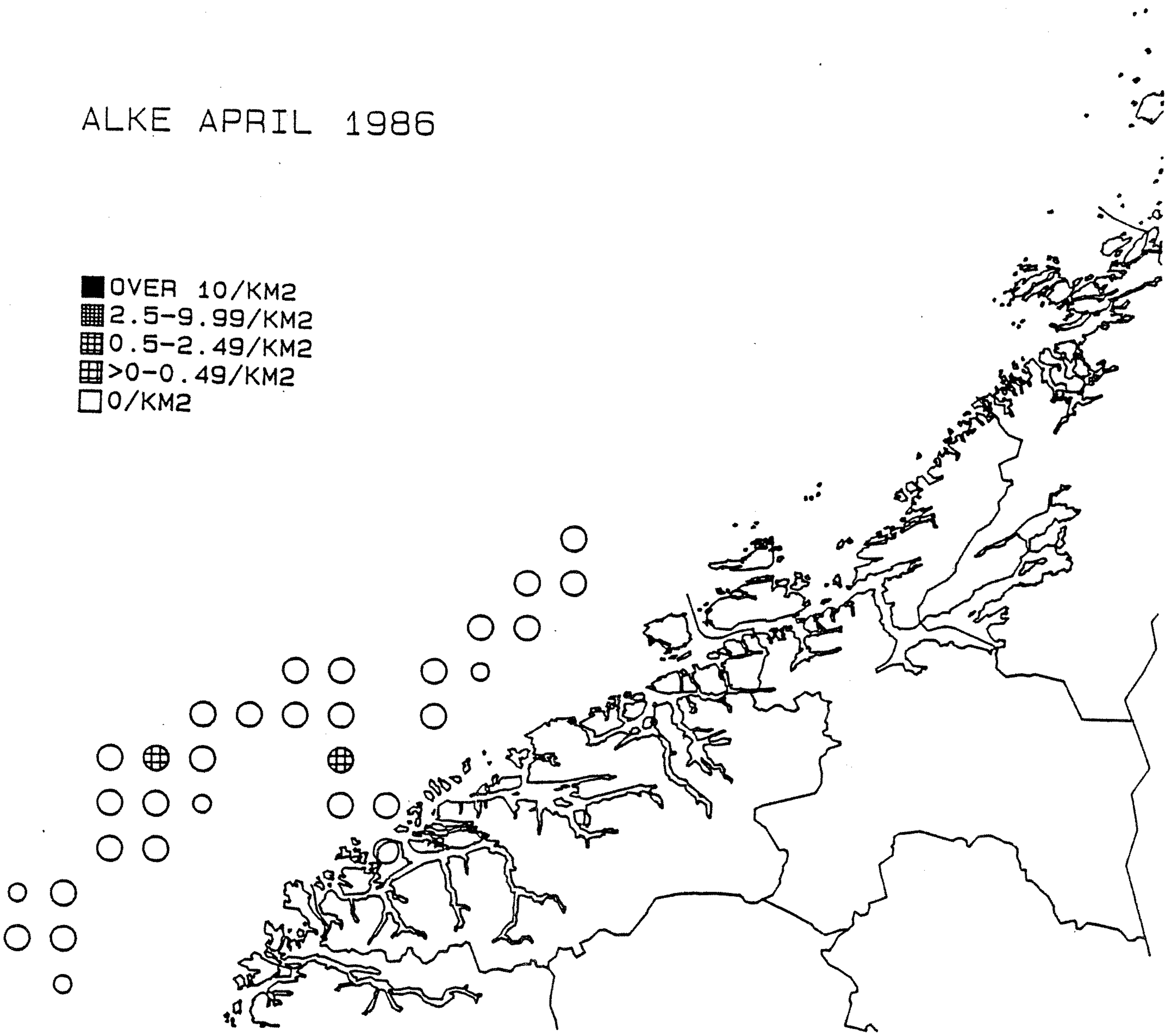


Fig. 3.17. Density of Razorbills <u>Alca torda</u> at sea 24.-30.4.1986. Small symbols show a survey distance of less than 6 km.

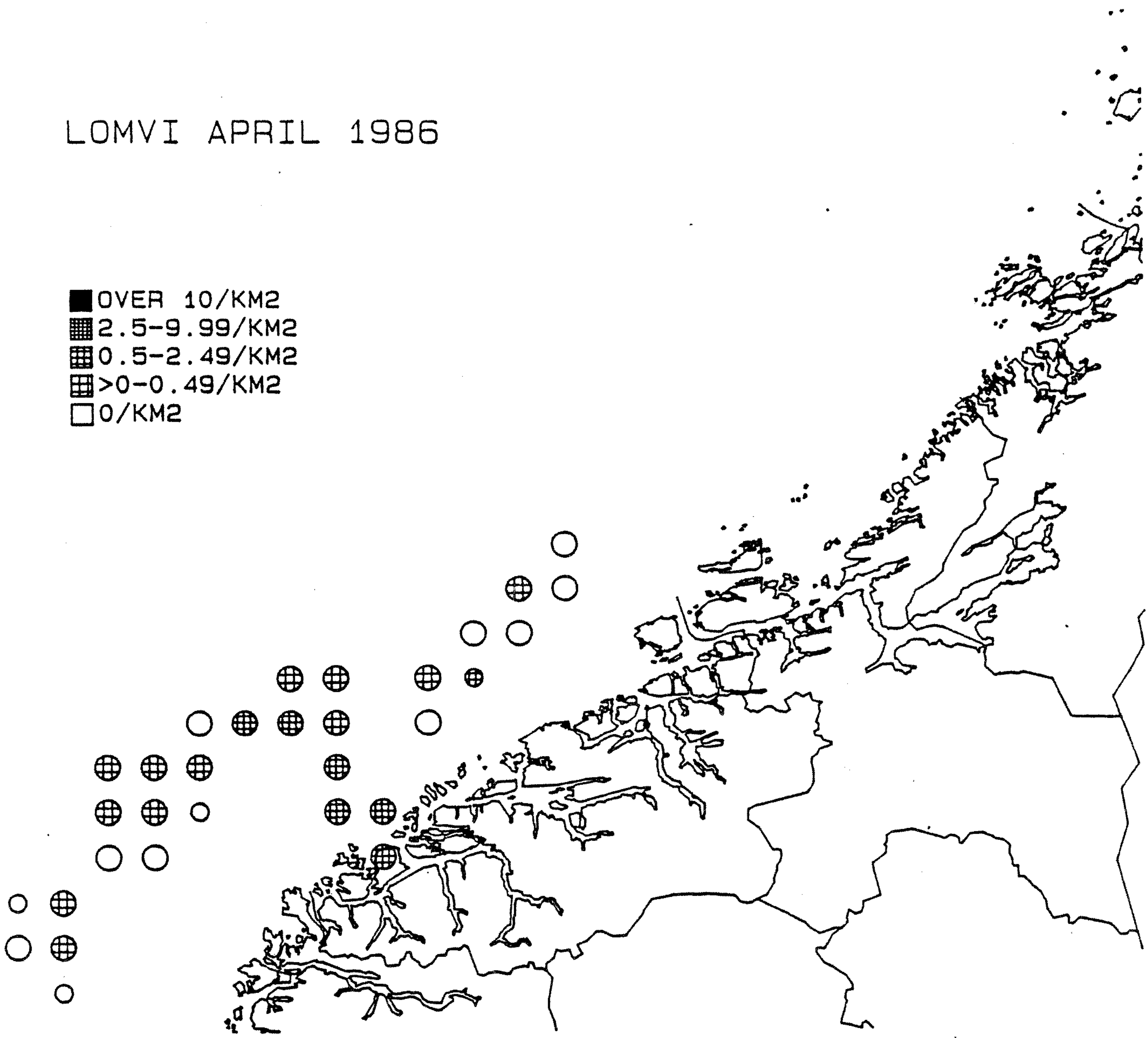


Fig. 3.18. Density of Guillemots <u>Uria aalge</u> at sea 24.-30.4.1986. Small symbols show a survey distance of less than 6 km.

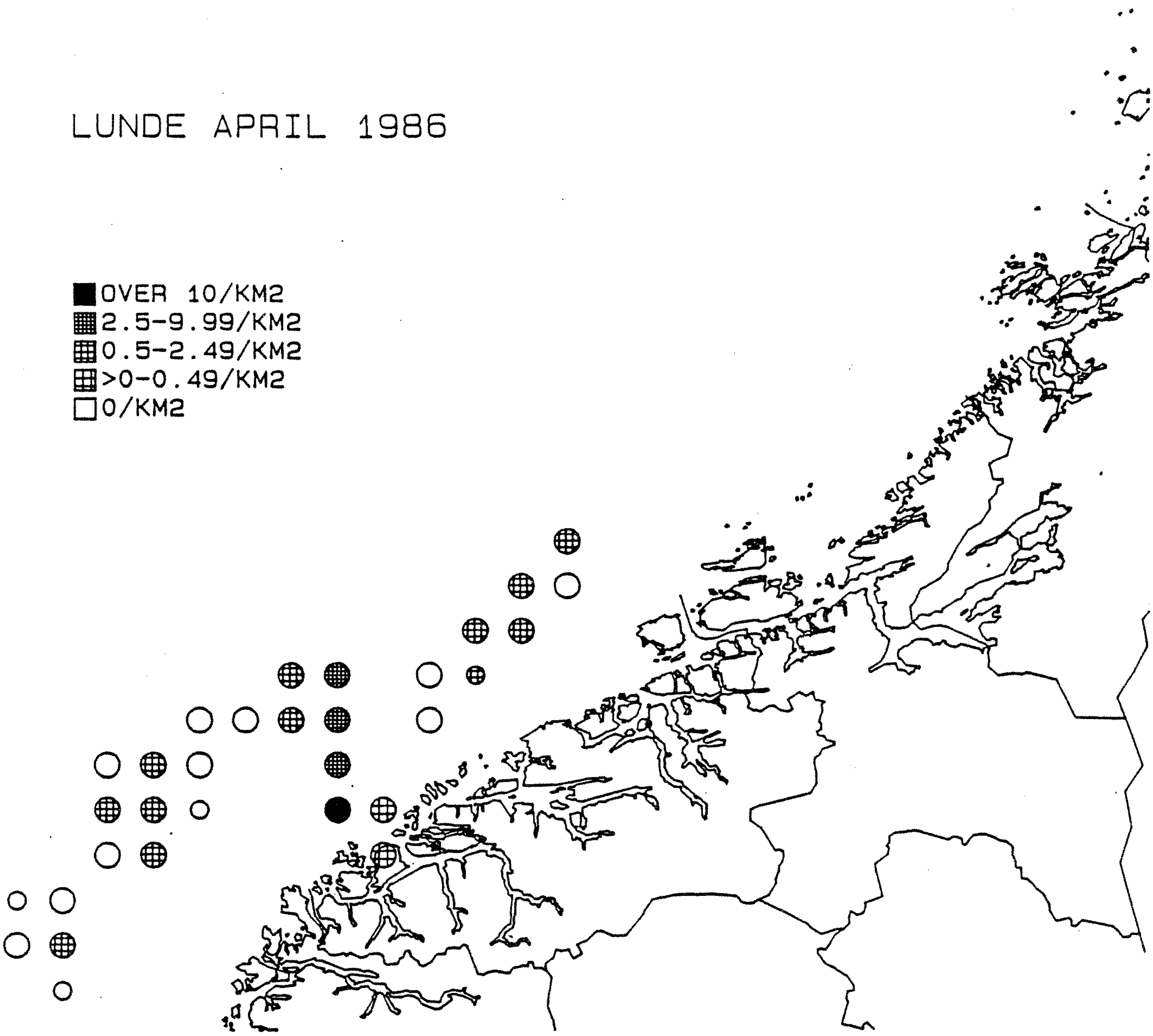


Fig. 3.19. Density of Puffins <u>Fratercula arctica</u> at sea 24.-30.4. 1986. Small symbols show a survey distance of less than 6 km.

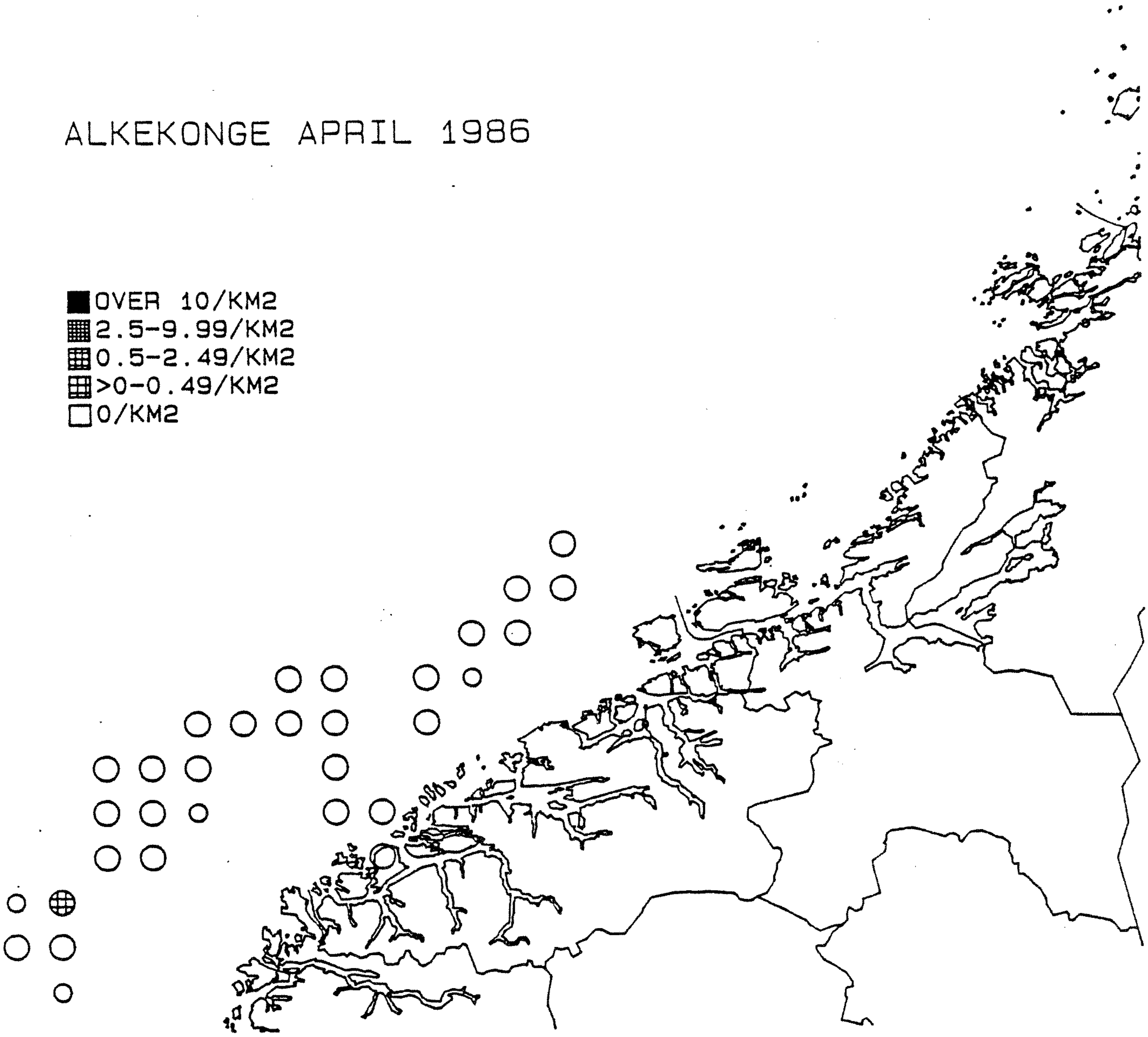


Fig. 3.20. Density of Little Auk <u>Alle alle</u> at sea 24.-30.4.1986. Small symbols show a survey distance of less than 6 km.

5.7 INSHORE MARINE MAMMALS

5.7.1 Introduction

This chapter describes the coastal bound species of mammals which have the potential of being affected by the petroleum activities on the Heidrun field. Although whales are elements of the coastal mammal fauna they are in this report treated in the offshore section. The consideration is extensively based on a recent review on marine mammals in Norwegian waters and the effects of petroleum activites on these (Griffiths & al. 1987). Other litterature is referred to when appropriate. Furthermore, Chapter 3.7 contains a review of effects of oil exploration activity on marine mammals in general and this section is relevant for mammals in the inshore area as well.

5.7.2 Effects of oil on seals

The true or phocid seals, including all seals in the northwest Atlantic, as well as the sea lions and the walrus, all have a relatively short coarse fur (pelage) with poor heat conservation abilities, and rely rather on dermal and subcutaneous blubber for insulation. The possible consequence of oil spillage on these animals deserves attention because of the great numbers of phocid seals found on the coast of Norway and Svalbard and in the Barents Sea. In particular, colonies of grey and common seals are found along almost the entire Norwegian coastline, ringed and bearded seals in the solid ice of Svalbard and drifting pack-ice of the Barents Sea, and herds of harp seals throughout the Barents Sea and occasionally also along the coasts of northern Norway.

Considering present tanker routes and the present and proposed distribution of drilling platforms it is almost certain that some seals would be affected by any future oil spillage. Griffiths & al. (1987) discuss the problems concerned with short-term oil exposure of mammals extensively.

We conclude that the available information is too conflicting to permit a clear answer to the question about what oil fouling would mean for Norwegian seals. There would likely be few acute deaths after contact with oil. A number of seals would probably die due to physical strain after heavy oil smothering, especially in the case of pups. A certain number would likely ingest enough oil to die, but it is not possible to say what proportion. More would suffer probably serious discomfort or pain due to sublethal intoxication. What may be significant, particularly in winter, is skin effects following chronic exposure to oil. There is some evidence that long-term oil exposure on phocid seals may cause dermatitis, but there needs to be experimental work to clarify this, especially the question of effects from leakage of stranded, weatered oil. If this is the case then the longer term results for badly fouled seals, especially seals in the pack ice, would probably be serious. Pups would not have the necessary weight gain to sustain life over the first year, and adults may suffer fatal frostbite.

5.7.3 Effects of oil on other coastal mammals.

As stated earlier the Heidrun field development will hardly pose a problem for deer. In contrast the mustelids, otter and mink which rely on fur for insulation, are placed at serious risk through contact with oil (Griffiths & al.,1987). The main effect that oil has is a matting of the hairs which disturbs the layer of air normally held in the underfur and increases heat conductance leading to hypothermia and often death. Animals that survive are at risk firstly from gastroenteritis from the oil they ingest during grooming, and secondly from lung and other infections secondary to the stress of prolonged hypothermia.

5.7.4 Impact of helicopter and boat traffic on coastal mammals

Coastal seal colonies, particularly of grey and harbour seals, can become accustomed to close approach of regular boat traffic such as ferries, although they will take to the water if an unfamiliar type of boat approaches. On two locations along the coasts of Denmark and England, they have also managed to hold to their original colony locations after the establishment of airforce bombing ranges in the vicinity (Tougaard, 1985).

Airborne noise sources also produce disturbance among marine mammal groups. Cowles & al. (1981) stated that harbour seals are susceptible to disturbance from low flying aeroplanes leading to mass exodus from hauling-out areas. If this happens during the breeding season, pups may be separated from their mothers with reduction of pup survival. Repeated disturbance can further lead to temporary or total abandonment of colony sites, both in phocid seals and in the walrus. Burns and Harbo (1977), quoted by Cowles & al. (1981), reported that spotted seals reacted strongly to the sounds of aircraft by running erratically across floes and diving off, whereas bearded seals reacted much more mildly.

In summary, coastal pinnipeds may tolerate an increase in service shipping and aircraft provided that the traffic is regular, but will be frightened and may even abandon their haul-out sites if subjected to a heavy traffic that comes at irregular intervals or approaches too closely. There may be a threshold frequency of boat traffic, as yet undetermined, beyond which permanent changes in behaviour and distribution become established.

5.7.5 Seals in the impact area

This chapter documents the species of seals in coastal and offshore Norwegian waters with emphasis on the two "mainland seals", the common (or harbour) seal and the grey seal. The five other species, the harp, hooded, ringed and bearded seal and the walrus, have a northern distribution (e.g., Figure 5.7.3 for harp seal) and will probably neither extend within the Heidrun area nor with possible open sea oil spills from Heidrun. Recent 'invasions' of harp seals along the coast may require a reevaluation of oil effects on this species, however.

Common seal

Common or harbour seals (Phoca vitulina) are coastal seals found (in Europe) from France northward to Svalbard, and around Iceland and Great Britain. In Norway localized breeding colonies are found among skerries and smaller rocky islands, both along the outer coastline and in some of the deep fjords along the entire coast (Table 5.7.1, Fig. 5.7.1). A small group of common seals has established itself on the western shore of Prins Karl's forland, West Spitsbergen, representing the most northerly extent of the species to date (Krog and Bjarghov, 1973).

The species is generally considered non-migratory, although seasonal movements do take place in some areas. In addition, some individuals may travel longer distances such as across the English Channel (Bonner and Whitthames, 1974).

Puberty occurs at five to six years of age in the male and three to four years for the female (Boulva and McLaren, 1979). Whelping extends usually from mid-June to mid-July for European seals (Bonner, 1972). The pups are almost always born on land (Boulva and McLaren, 1979), but are able to swim from the moment of birth and may begin to enter the water from the first day. Lactation in the British population lasts for some three to four weeks (Harrison, 1960; Curry-Lindahl, 1975) and mothers make daily feeding excursions to sea during

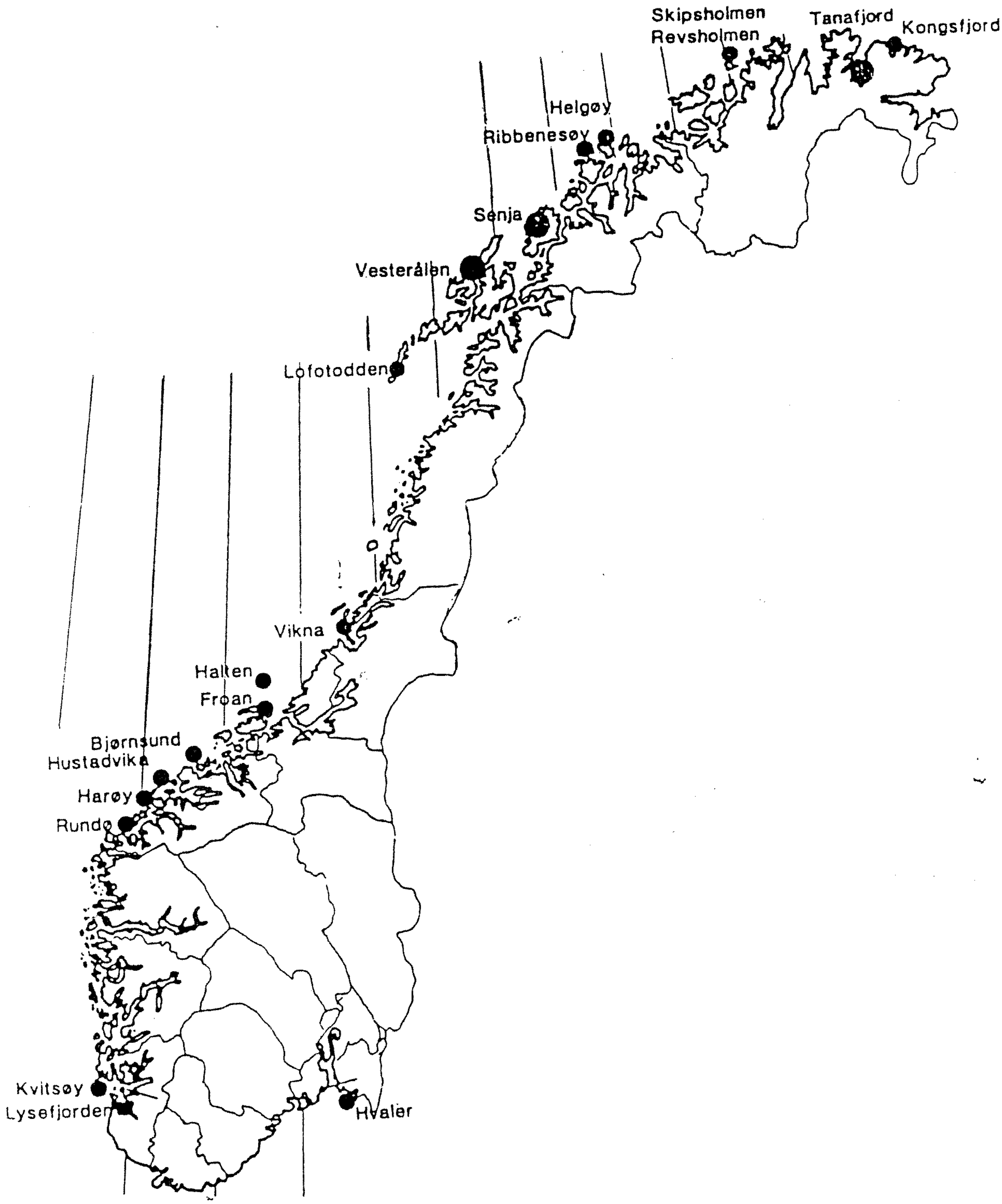


Figure 5.7.1. Distribution of larger common seal colonies along the Norwegian coast.

Table 5.7.1. Common and grey seals in Norway. Minimum numbers estimated from direct counts. (Source: Sea Mammal Section, Institute of Marine Research, Bergen, current Oct. 1986).

County	Common seal number	Grey seal number
Finnmark	380	350
Troms	700	150
Nordland	450	860
Nord-Trøndelag	240	230
Sør-Trøndelag	450	1400
Møre-Romsdal	1240	10
Sogn-Fjordane	370	50
Hordaland	30	0
Rogaland	105	120
Vest-Agder - Swedish Border	455	0
Total	4420	3170
Probable range	4500-6000	3500-5000

lactation. Mating occurs in August and early September about two weeks after weaning (Harrison, 1960). The mating period is preceded by fighting between the males that can be violent (Sullivan, 1981). Mating is initiated by the male and always occurs in the water (Venables and Venables, 1957; Allen, 1985). The length of diapause is not clear for European populations, but implantation probably occurs in early November after a delay of some two and one half months, based on calculations from American populations.

Moulting of the adult pelage occurs annually, probably in July and early August before the beginning of breeding (Venables and Venables, 1957).

Newly weaned pups feed on bottom dwelling crustacea for several months. Older animals feed on a variety of fish, cephalopods and crustaceans including herring, cod, salmon, and flatfish and consume about 5% of the body weight per day. Feeding is thought to occur mostly in the early morning.

Factors of possible relevance to oil pollution:

1. Harbour seals are permanently resident along coasts and do not move over great distances.
2. Pups swim at a few days of age and would become oil-fouled by any

oil slick present.
3. Lactating females would become oil-fouled during their daily feeding excursions, possibly transferring oil to pups.
4. Serious depletion of crustacea and other invertebrates from oil toxicity could threaten first year seals but probably not older animals.
5. Harbour seals are flighty and disturbance during oil spill cleanup operations could cause temporary abandonment of haul-out sites.

Grey seal

Coastal populations of grey seals (Halichoerus grypus) are found along the coasts of the United Kingdom, Ireland, Iceland, the Faroe Islands, Norway, the Kola Peninsula, eastern Canada and Greenland, while ice-breeding population occur in the Baltic Sea and the Gulf of St. Lawrence. In Norway there is a local coastal seal differing in distribution and behaviour from the common seal, by preferring more exposed skerries and rocky islets along the outer coastline. Discrete populations or individual wanderers can be found on along most of the coast although the bulk of the population and the major breeding groups occur mainly in the South Trøndelag area and further north, from latitude 63^0N to 68^0N (Figure 5.7.2) (Wiig, in press). The population in Norway is currently estimated at between 3 500 and 5 000 animals (Table 5.7.1). In England the population is increasing annually at a rate of some 5%-6%, and the same is probably true for Norway. The species does not migrate in the strict sense although a non-directional dispersal takes place after breeding, with a corresponding congregation before breeding (Bonner, 1981).

Most of the knowledge concerning East-Atlantic grey seal biology comes from United Kingdom sources, but the Norwegian population appears not to differ significantly. There are differences in breeding biology between the Baltic and Russian groups and the European group (Hook and Johnels, 1972; Curry-Lindahl, 1975). In principle the details presented here are also valid for Norwegian grey seals.

Whelping is spread over a two-month period with the peak in mid-October, and occurs on rocky islands lying some distance from the coastline (Bonner, 1981). Adult breeding males and pregant females begin to congregate in the breeding areas in September. However, the pattern of male dominance over groups of females which is pronounced in British grey seal colonies (Henwer, 1960; Anderson, Burton and Summers, 1975) has only been observed at very few locations in Norway,

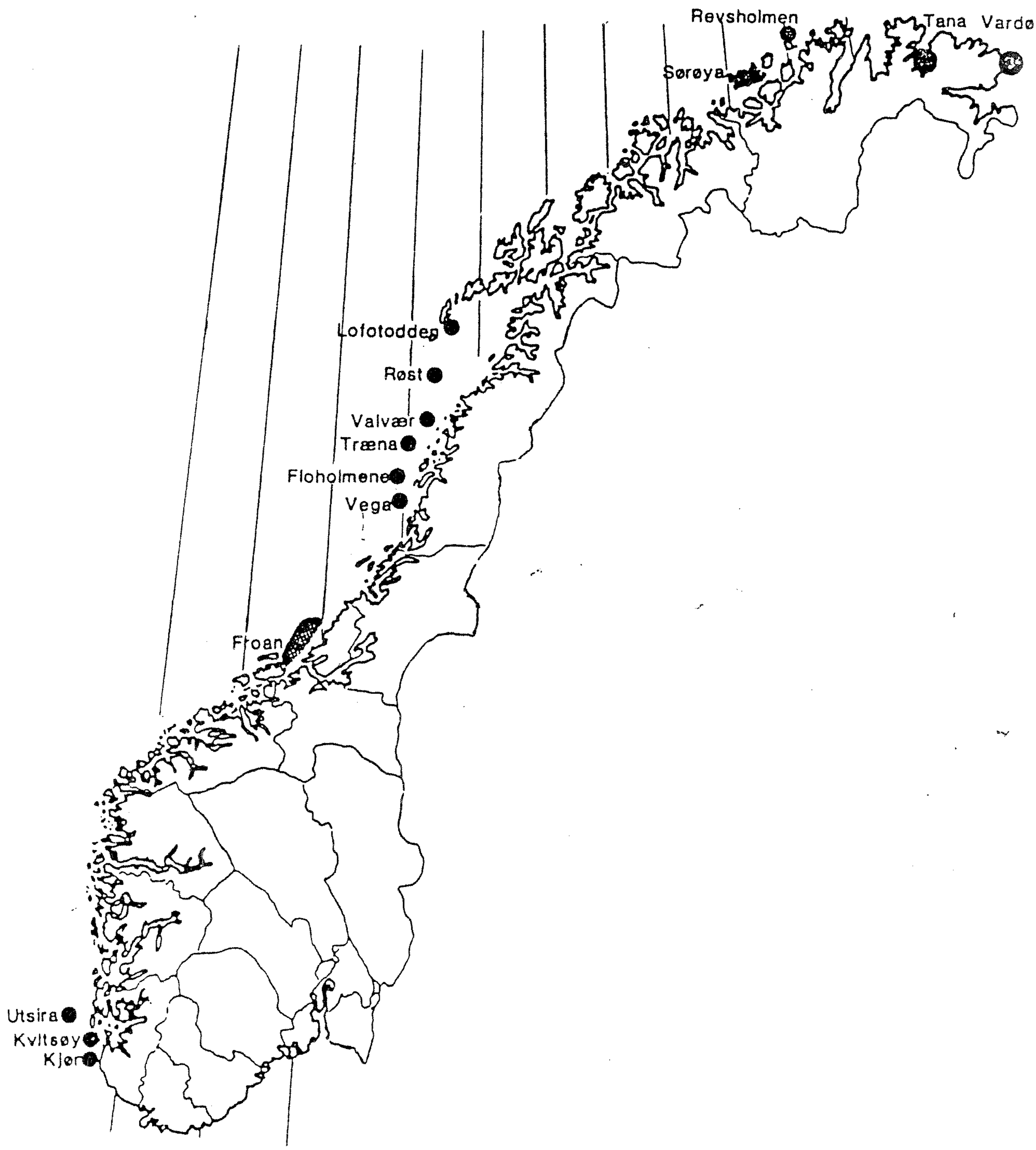


Fig. 9. Distribution of larger grey seal colonies along the Norwegian coast.

where most breeding grey seals appear to establish family groups (male, female and pup) through the season (Ø. Wiig, pers. comm.). Lactation lasts for 14-17 days and is followed after a few days by oestrus and copulation (November). Females remain on the islands only until they have mated and make trips to sea to feed or if disturbed whilst nursing their pups. Pups remain on the islands for some weeks after weaning before taking to sea, often lying protected in small pools. They are generally described as avoiding the water, but we have seen occasional examples of young pups swimming with their mothers. As in other seals there is a period of embryonic diapause lasting for some 100 days, with implantation occurring in February. For most of this period the pregnant cow is at sea feeding.

Moulting takes place at the beginning of February for the adult femals and in March for the adult males (Backhouse, 1960). Animals haul out onto rocky islands for considerable periods during the moult but not necessarily at the same location as that used for breeding. Feeding is either reduced or stops completely during the moult (Bonner, 1981).

Grey seals feed near the coast (Bonner, 1981). The diet covers a wide variety of fish, with also smaller numbers of crustacea and mollusca. Cod, salmon, herring and flatfish are the prime fish species eaten, apparently by all age classes right from newly-weaned. The daily food intake is estimated at between four and five percent of the body weight.

Factors of possible relevance to oil pollution:

1. The species does not migrate and is found in coastal waters throughout the year.
2. During the breeding season females regularly enter the water and could transfer oil to the pups even if the pups stay on land.
3. The variety of fish eaten suggests that the potential risk of mortality due to death of prey species is reduced.

5.7.6 Otters in the impact area

The European otter (Lutra lutra) in Norway is not strictly a marine mammal, but occurs on coastlines and feeds along seashores. The otter is found throughout Norway, but rare. The strongest remaining population is found in Finnmark. Unpublished observations indicate a concentration of otters in the Vikna area (Bronndal, pers. comm.).

Little is known of the biology of the otter. Males reach a weight of eight to twelve kilograms and a length of about 120 cm, while the corresponding figure for females is six to ten kilograms and 110 cm (Harris, 1968). Adults are solitary and are seen together only during the breeding season. In coastal areas, they feed on beaches and up to a hundred or so metres offshore, and eat a wide range of fish, crabs and other invertebrates. When diving, the ears and nose are sealed and animals hunt using vision and tactile sense through the sensitive vibrissae.

The gestation period is probably 61 days and most births occur in late winter and early spring, although there is no fixed season. The litter size is usually three to five. Mating occurs after weaning of the litter, and there is apparently no diapause. Mating occurs both on land and in the water.

Factors of possible relevance to oil pollution:

1. The species is already rare and declining and careful attention should be given to the harmful effects of oil-fouling and ingestion.
2. Oil is reported to kill a high percentage of contaminated otters.

5.7.7 Other coastal bound mammals

Besides the otter mink is a habitual user of the littoral zone. The mink populations along the coastline is partly recruited from farm-mink. The mink population within the influence area of an eventual Heidrun oilspill is assumed to be substantial. Population estimates based on proper field work are not available, however.

External oiling would probably be fatal to mink - as for otter and seabirds - and ingestion of oil through prey species and cleaning of the fur would give toxic effects as described below.

Deer in general is considered as infrequent user of the littoral zone - and the general human activity concerned with an oilspill would probably keep this group of animals away from contact with oil.

5.7.8 Seal populations vulnerable to oil contamination

Grey seals, common seals and harp seals are considered susceptible to contact with oil in the Heidrun influence area. The distribution of grey seals in Norway is indicated in Table 5.7.1 and Fig. 5.7.2. The most important breeding area is the coast of South Trøndelag, particularly the islets and skerries in the Halten-Froan archipelago. This part of the coast is considered to be within the medium impact zone (Chapter 5.1) for oil pollution from the Heidrun field, and where fouling of grey seals by oil is already significant. Over a third of the grey seals born at Halten-Froan in recent years have been partially or heavily coated by oil which possibly has drifted from the Statfjord field (Wiig, in press). Oil-fouling of this grey seal population can be expected to increase in the coming years, but one should also note that the breeding period in autumn coincides with the season when oil from the Heidrun field is least likely to hit the coast south of Vikna.

The coast of Nordland, which contains the next greatest population of grey seals, should be even more at risk, containing both high and medium impact zones. On the other hand the the grey seal population here is large mainly because of the long coastline. In reality individual grey seal colonies are quite small and dispersed and perhaps not a great number would be affected by a single spill. The seal population of the Lofoten-Vesterålen region is poorly documented, and has not been properly surveyed since 1964 (Øynes, 1964). Seal numbers along this coast can therefore only be guessed. The Finnmark coastline also contains a large grey seal population, that would certainly be affected by spillage of oil from the Barents Sea leases no matter what season. It is therefore expected that it is the South Trøndelag grey seal population that will take the brunt of any oil pollution in the immediate future, including any oil accidentaly discharged from the Heidrun field, mainly because of its density.

The Norwegian harbour seal population has its greatest concentration located on the Sogn- Fjordane, Møre-Romsdal and South Trøndelag coasts, which will possibly be the most oil polluted Norwegian coastline for at least the next decade, due to petroleum activities. However, only the South Trøndelag, and possibly Nordmøre, populations will be in jeopardy to oil from the Heidrun field

During the active feeding phase of their annual cycle (late summer to winter) large numbers of harp seals are found in the southern Barents

Sea and along the east Finnmark coast (Fig. 5.7.3). The seals also penetrate deep into Varangerfjord and Tanafjord and recently south to Møre. Free-swimming harp seals in the Heidrun influence area are likely to be contaminated by oil if a blowout occurred during the winter. These seals are, however, free swimming and do not normally haul out on shore, so that we can speculate that oil contact might be brief and quickly rinsed off by clean sea water.

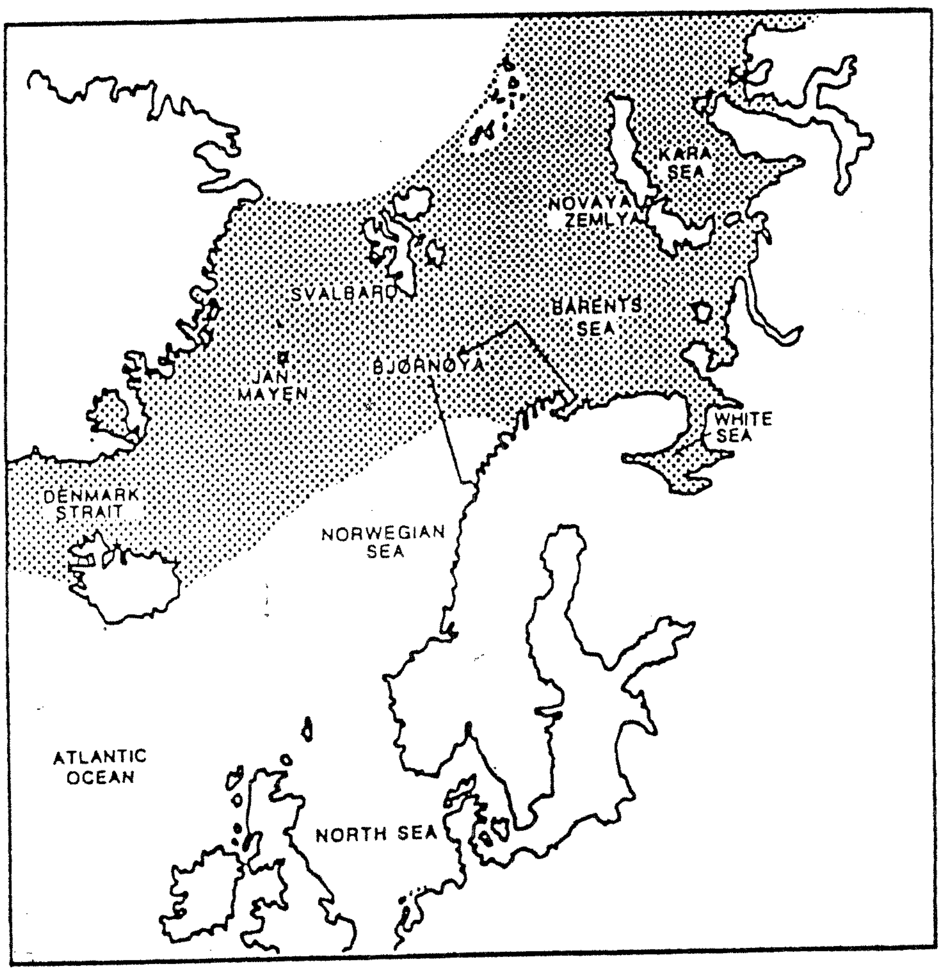


Figure 5.7.3. Harp seal distribution in the Northeast Atlantic

5.7.9 Conclusions

Oil leakages from the Heidrun field and connected traffic will increase the oil fouling of the major common and grey seal colonies from Nordmøre to Southern Troms perhaps particularly the Froan, Halten, Vikna, Vega, Floholmane, Træna and Valvær colonies. The effects of this oil contamination in terms of individual suffering, changes in food requirements/heat balance and population development are presently unknown and potentially severe. The effects should be subject to research by experimental work on captive seals and collection of samples from free living seals.

A Heidrun oil blow-out reaching the grey and common seal colonies during the spring pupping seasons may decimate the populations. A team of seal biologists and veterinarians should be trained and mobilized for field studies in case of a blow-out.

Oil leakages from the Heidrun development and connected traffic may deplete populations of European otter in the influence area, whereas a blow-out has the potential of killing all otters along oil contaminated beaches. A plan for preventing oil from reaching the most important otter areas should be worked out. The possibility for endangering the future survival of this species in Norway must be subject to further evaluation.

The Heidrun activities will probably not have any significant effects on deer, reindeer and mammals used in husbandry, but this view ought to be substantiated by literature studies and interviews with local farmers.

5.8 NATURE RESERVES, PROTECTED AREAS AND AREAS OF SPECIAL SCIENTIFIC INTEREST

5.8.1 Introduction

The basis for defining areas as protected or proposed protected is their value either due to occurrence of particularly vulnerable or valued ecological communities or species of plants and animals. General these two considerations are tightly bound. The effects of oil on the various sensitive elements of the coastline have been outlined in the previous chapters. The present chapter presents and discusses the distribution of such defined areas. The chapter also presents areas of special scientific interest.

Among protectected and proposed protected areas inside the impact zone, we will only treat those areas that may be affected by the activity on the Heidrun field. This means that most of the areas will be either tidal flats, areas with supralittoral vegetation or sites important to birds. Also the two first mentioned types may often be important to birds.

The registration of areas of interest to nature conservation but not protected today, is based only on offical goverment documents and plans. The information from/about each county are thus comparable. We have not included registrated sites which is just called "worth protection". This is an expression which may vary in content from person to person and from place to place. (Cf. chap. 5.2 and 5.5 about shore types and sensitivity to oil spill.)

5.8.2 Protected and proposed protected areas

Protected areas are presented according to "Oversikt over naturområder og forekomster i Norge og Polarområdene som er fredet eller vernet pr. 1. januar 1985" (Protected nature areas in Norway by 1.1.85) compiled by Ministry of environment 1985. Personal contacts have updated the data to 1. January 1987. This information include national parks, nature reserves, protected landscapes, other protected areas, nature memorial, species protection and lighthouses with protection of birds.

NOU 1986:13 "Ny landplan for nasjonalparker" (New countryplan for national parks) presents proposals for new national parks, nature reserves and protected areas. Four areas in Nordland county which may be affected by the activity at the Heidrun field are proposed protected, but no one in Nord- and Sør-Trøndelag.

The Fylkesmannen in each county have made drafts to protection plans for wetland areas. In Sør-Trøndelag, all areas at the coast which were proposed protected in the draft to protection plan, are today nature reserves or protected areas.

All areas are listed and shown on figs. 5.8.1 to 5.8.4.

5.8.3 Areas of special marine ecological scientific interest

According to contact with Distrikshøygskolen i Bodø (NDH, S. Skreslet, pers. comm.), no particular area in Nordland county is pointed out to be of special scientific or educational use to NDH at the moment. Contact with the University of Trondheim (T. Strømgren, pers. comm.) states three areas in the two Trøndelag counties with such classification.

Areas of Froan in Frøya municipality and an area of islands in the outer south part of Vikna municipality (see map) are currently used in marine biological research. Sletvik Marine Biological Field Station is situated in the outer part of Agdenes municipality.

According to the SINTEF reports Kystplanlegging (Hoddø & al. 1984, Klokk & al. 1984, Tømmerås & al. 1985) there are three sites important in education and/or reserach. All this are situated in Sør-Trøndelag; Aunøya in Hitra municipality, Gaulosen in Trondheim/Melhus and Ladehamrene/Devle in Trondheim.

The sites are shown on the map for protected areas in Nord- and Sør-Trøndelag.

5.8.4 Presentation of sites

All protected and proposed protected areas in Nordland, Nord-Trøndelag and Sør-Trøndelag counties that may be affected by the activity on the Heidrun field are listed in tables 5.8.1 to 5.8.6. Lighthouses with protection of birds are listed in table 5.8.7.

Protected, proposed protected and areas of special scientific interest are also shown on figures 5.8.1 to 5.8.3. Lighthouses with bird protection are shown on figur 5.8.4.

The numbers of the areas in the tables correspond with the numbers on the figures.

Table 5.8.1. **NORDLAND PROTECTED AREAS**

Nr	Name	Municipality	Description
1	Skogvoll	Andøya	Nature reserve Tidal flat.
2	Skittenskarv-holmene	Værøy	Nature reserve
3	Bekkenes-holmen	Tysfjord	Nature reserve
4	Karlsøyvær	Bodø	Nature reserve Coast landscape. Area for birds. Birdprotection 2 km away from resreve.
5	Bliksvær	Bodø	Nature reserve Important bird biotope

Table 5.8.2. **NORDLAND** NOU 1986:13 Proposed protection areas

Nr	Name	Municipality	Description
6	Røstøyene	Røst	Proposed protected area incl. several bird reserves. Bird resort of international value.
7	Indrefjord Øksfjord	Lødingen (mainly)	Proposed national park. Coastalpine nature. Mostly low sensitivity to oil spill.
8	Svellings-flaket	Lødingen	Proposed nature reserve. Important for birds.
9	Helgelands-øyene	Vega	Proposed protected area. Vegetation, animal life and ladscape of high value.

Table 5.8.3. **NORDLAND** Nordland county: Draft to protection plan for wetlands.

Nr	Name	Municipality	Description
10	Aaholmen	Andøy	Marsh. Important in bird migration
11	Risøysundet	Andøya	Tidal flat. Important in bird migration.
12	Grunnfjorden	Øksnes	Tidal flat. Important bird biotope
13	Straume	Bø	Tidal flat. Important to birds.
14	Grunnfør	Hadsel	Tidal flat. Important to birds.
15	Røstlandet	Røst	Supralittoral vegetation. Important bird biotop
16	Kjerkvatnet	Evenes	Important in birdmigation and moulting.
17	Lilandsvatnet		Tidal flat.
18	Steinlands-vatnet	Hamarøy	Important for birdbreeding.
19	Seinesodden	Bodø	Supralittoral vegetation Tidal flat. Important birdbiotope
20	Drevjaleira	Vefsn	Tidal flat. Important in bird-migration. Many bird species.

Table 5.8.4 **NORD-TRØNDELAG PROTECTED AREAS**

Nr	Name	Municipality	Description
21	Leknesøyene	Leka	Areal protection Tidal flat. Many bird species. Used in overwintering and migration
22	Kvaløy and Rauøy	Vikna	Nature reserve. Species protection.
23	Borgann and Frelsøy	Vikna	Nature reserve. Species protection.
24	Kjønnsøyhopen	Vikna	Protected area. Supralittoral vegatation Bird overwintering.
25	Kanalen	Nærøy	Nature reserve. Only partly salt water. Important bird area.
26	Åsnes	Namdalseid	Nature reserve. Supralittoral vegetation
27	Tautra	Frosta	Nature reserve. Tidal flat. Very important area for birds. The area is of international importance.

Table 5.8.5 **NORD-TRØNDELAG** Nord-Trøndelag county : Draft to protection plan for wetlands.

Nr	Name	Municipality	Description
28	Rinnleiret	Levanger and Verdal	Supralittoral vegetation. Many bird species. Important to bird migration
29	Sandfærhus	Stjørdal	Supralittoral vegetation. Important to migration and overwintering of birds.

Table 5.8.6. **SØR-TRØNDELAG PROTECTED AREAS**

Nr	Name	Municipality	Description
30	Froan	Frøya	Nature reserve. Protected land-scape. Species protection. Area of international value. Very important to birds and seal
31	Bingsholms-råsa	Åfjord	Protected area. Shallow area important to birds
32	Været	Bjugn	Protected landscape. Species protection. Tidal flat. Important to birds.
33	Innstrands-fjæra	Ørlandet	Protected area. Tidal flat. Important to birds.
34	Hovsfjæra	Ørlandet	Protected area. Important to birds
35	Grandefjæra	Ørlandet	Nature reserve. Very important tidal flat. Very important to birds.
36	Kråkvågsvaet	Ørlandet	Protected area. Supralittoral vegatation. Important to birds.
37	Stømmen	Rissa	Protected area. Supralittoral vegation Important to birds.
38	Grønnings-bukta	Rissa	Nature reserve. Tidal flat. Important to birds.
39	Gaulosen	Melhus	Nature reserve. Tidal flat. Important to birds.
40	Leinøra	Trondheim	Nature reserve. Tidal flat. Important to birds.

Table 5.8.7. Lighthouses with protection of birds.

Nr.	Lighthouse	County	Municipality
1	Litløy	Nordland	Bø
2	Værøy	Nordland	Verøy
3	Rotvær	Nordland	Lødingen
4	Tranøy	Nordland	Hamarøy
5*	Støtt	Nordland	Meløy
6*	Sklinna	Nord-Trøndelag	Leka
7	Måholmen	Nord-Trøndelag	Vikna
8	Nærsund	Nord-Trøndelag	Vikna
9*	Ellingråsa	Nord-Trøndelag	Flatanger
10	Buholmråsa	Sør-Trøndelag	Osen
11	Halten	Sør-Trøndelag	Frøya
12	Finvær	Sør-Trøndelag	Frøya
13	Vingleia	Sør-Trøndelag	Frøya
14*	Åsen-Vågøy	Sør-Trøndelag	Bjugn
15*	Tarva	Sør-Trøndelag	Bjugn
16	Kjeungskjer	Sør-Trøndelag	Ørland
17	Terningen	Sør-Trøndelag	Hitra

* Shut down lighthouses.

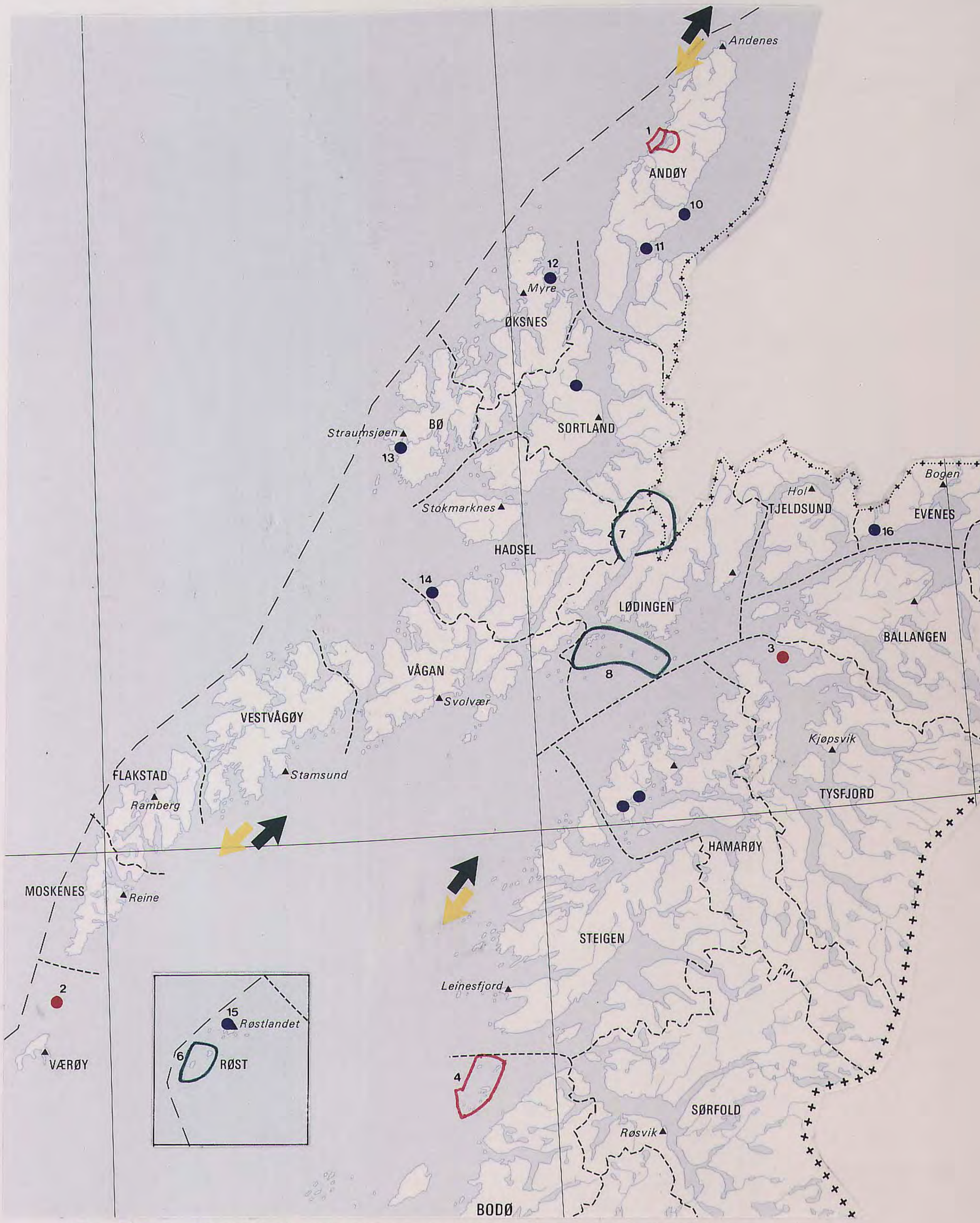


Fig 5.8.1 Protected and proposed protected areas in Nordland county. Areas of scientific interest.

- Protected area.
- Proposed protected in NOU 1986:16.
- Proposed protected in the county's wetlandplan
- Area of special scientific interest

Impact zones: high, medium, low.

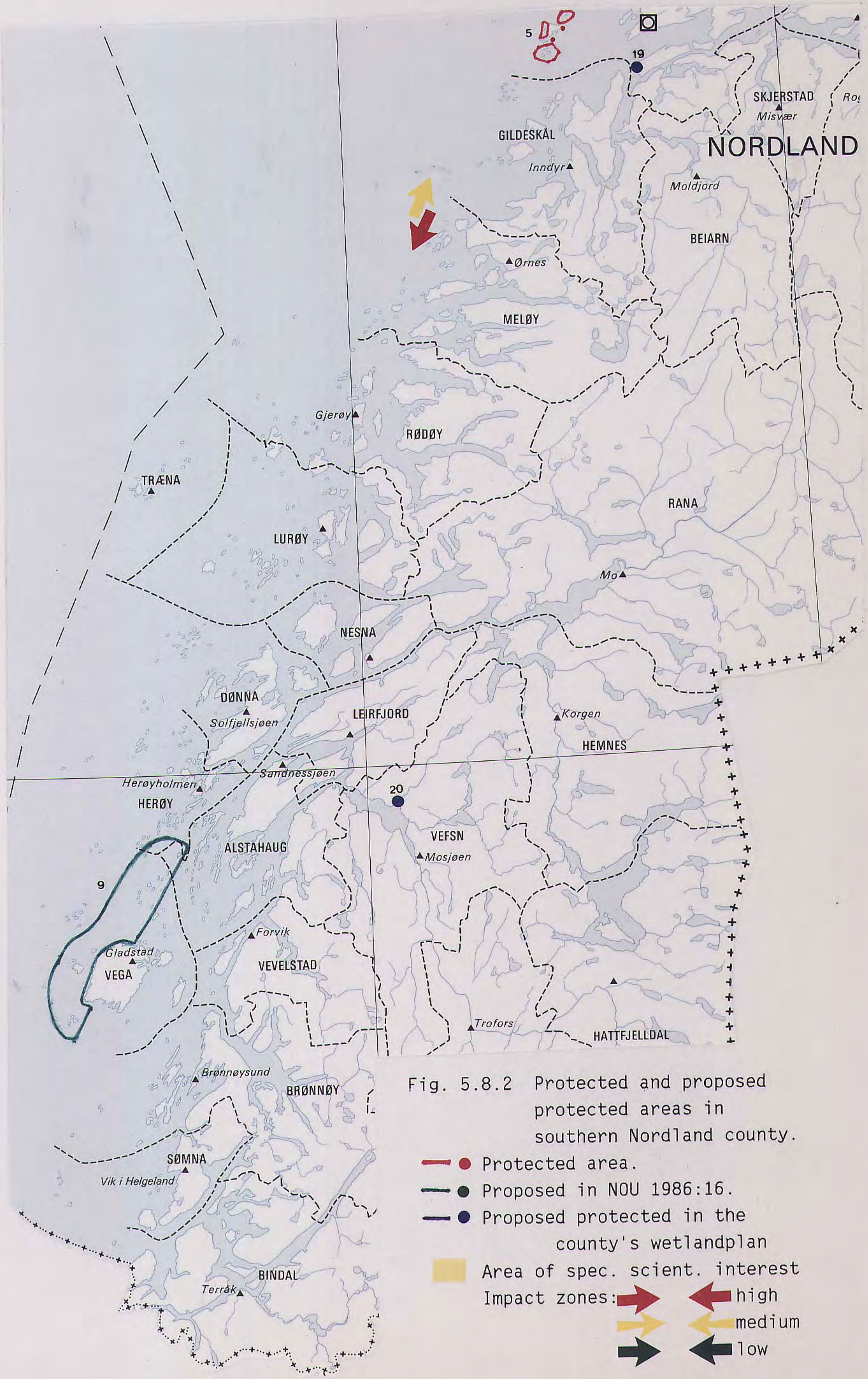


Fig. 5.8.2 Protected and proposed protected areas in southern Nordland county.

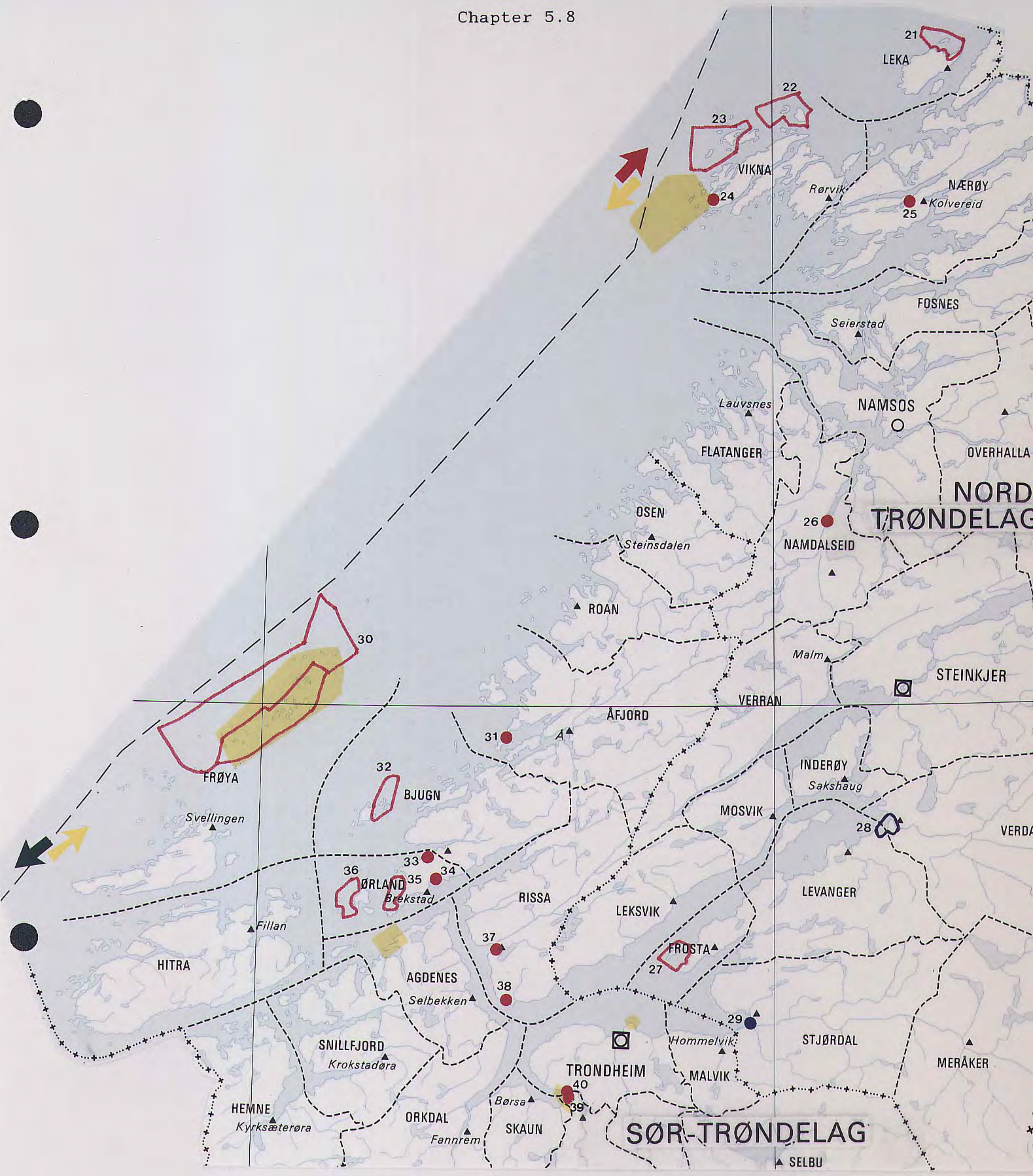


Fig 5.8.3 Protected and proposed protected areas in Nord- and Sør-- Trøndelag counties. Areas of scientific interest.

Protected area.

Proposed protected in NOU 1986:16.

Proposed protected in the county's wetlandplan

Area of special scientific interest

Impact zones: high, medium, low.

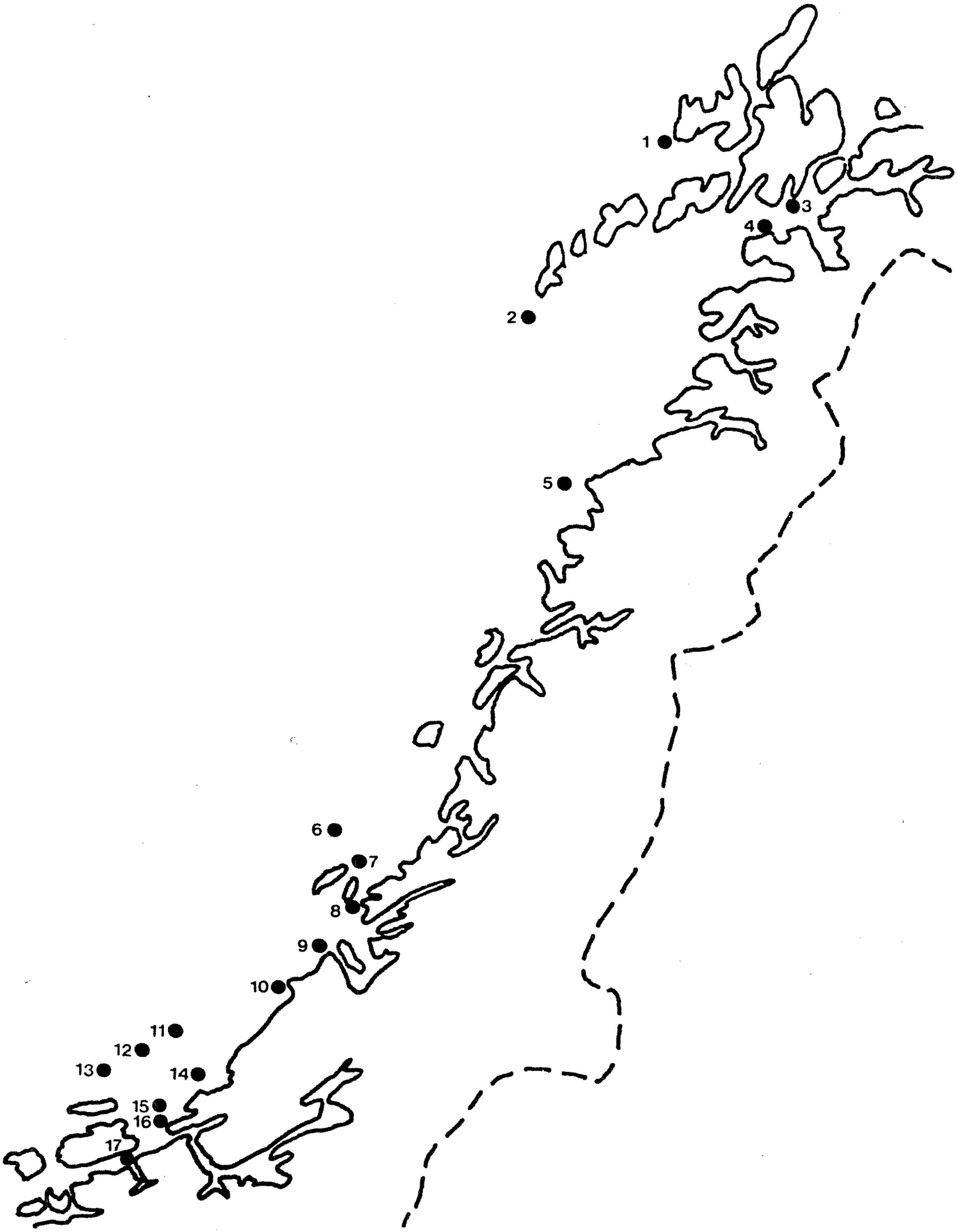


Fig. 5.8.4 Lighthouses with birdprotection
Numbers correspond with table in chap. 5.8.4

5.8.5 Conclusions

The areas which are important to nature conservation are grouped in three major regions. One is on the border between high and medium impact zones (cf. chap. 5.1) and two are in the medium impact zone.

The Vikna - Leka coastline is considered to be inside the high impact zone during spring and summer, and the medium impact zone for the rest of the year. In this region there are one area important for scientific research, two nature reserves and two protected areas. All the protected areas are of great importance due to bird populations.

The Froan archipelago, the outer and parts of inner Trondheimsfjord are of great importance to nature conservation. Froan and the outer part of Bjugn, Ørland and Agdenes municipalities are of particularly high value. Here there are two areas important to scientific research and a large number of nature reserves and protected areas of both national and international value. The Froan region will be particulary vulnerable to an accidental oil spill at Heidrun, both because the archipelago is on the open coast, and since it is within the medium impact zone for most of the year (except in autumn). The region of Trondheimsfjorden and the entrance to the fjord are considered somewhat less threatened, because the probability that oil from Heidrun will enter these regions is less than for Froan, and because the possibility for successfull oil spill cleaning is improved.

In Bodø municipality, in the medium impact zone, two nature reserves, both important to birds, are recorded. Since the probability of oil entering this coastline is greatest in spring and summer according to the oil spill model, these bird populations will be in particular danger during the sensitive breeding season from April to September.

The proposed protected area Helgelandsøyene in Vega municipality lies in the high impact zone, and the consequences of an oil spill affecting this region is considered to be the same as for Froan further south. The Værøy-Røst region is also of importance to nature conservation, especially during summer when the spill model forecasts an impact on this coastline.

5.9 HUMAN USAGE OF THE MARINE ENVIRONMENT

5.9.1 Introduction

Human usage in this connection is restricted to outdoor life and recreation. Industrial use (fishing, aquaculture) is treated in previous chapters.

Better living conditions and more spare time enable people to use more of their time on recreation. Probably, the value of the coastal zone as recreational site may increase in the future.

Contamination of the coastline by oil spill can seriously reduce the value for human usage. Depending on the extent of the contamination and the self cleaning ability the recreational value of an area can be lost for a shorter or longer period. Besides the practical cleanup problems with contamination of marinas, quais, moorings and yachts, the oil spill may cause harm to the coating on surface of hulls.

In this chapter we present all areas of recreational value along the coast in Sør-Trøndelag, Nord-Trøndelag and Nordland counties. The examined coastline from Hitra to Andøya contains the zones were it is medium to high possibility that any oil spill from an accident at the Heidrun field would contaminate the coast.

The inner part of some of the deep fjords is not assessed. This means that areas in Beistadfjorden, the innermost part of Trondheimsfjorden, inner parts of Vefsnfjord, Ranafjord and Sørfold are not registered. The reason for this is partly that oil is less likely to reach these areas, partly that there is a strong possibility of preventing oil from entering these areas by mechanical means.

Types of usage which are included are outdoor life, bathing, sportsfishing, excursions by private boats, etc.

Other reports have been prepared with the same purpose. Important publications are the SINTEF sensitivity maps "Kystkartlegging" which have been prepared for each county (Cf Hoddø & al. 1984, Klokk & al. 1984 and Tømmerås & al. 1985 for the relevant counties).

5.9.2 Method

In this report the value of usage of an area has been compared with it's sensitivity to oil spill. An assessment is first made on the value of usage of each area. If the area is just of minor, local importance it is given value L (low). If it has major, regional importance it is given value H (high). Value M (medium) implies an importance between L and H.

Secondly the areas are assessed for sensitivity to oil spill. This is based on the selfcleaning ability of shores (cf Chapter 5.2), since the duration of smothering is a prime factor for recreational recovery of an area.

The SFT (1984) report gives data on the selfcleaning ability of shores:

Biotope type	Self cleaning ability
Salt marsh Supralittoral vegetation Muddy shore Tide pool Lagoon Bays with driftwood	small
Sandy shore Gravel beach	small/medium
Boulder beach	medium
Rocky shore Rocky headland	great

The type of shore of each area is examined according to SINTEF "Kystkartlegging". The degree of sensitivity is given according to SFT's table of self cleaning ability so that the SFT expression "great" selfcleaning ability corresponds with sensitivity value L (low), "medium" corresponds with value M (medium) and "small" with value H (high).

The selfcleaning ability of a shore will vary according to the exposure to waves. Protected shores will have lower selfcleaning ability than similar type exposed shores. This has not been taken into account in the assesment of the sensitivity to oil spill of each area. This item will instead be discussed later.

Thirdly, the sensitivity is compared with value of usage. A highly valuable area with high sensitivity (low selfcleaning ability) ought to be given priority in the planning of oil spill protection. The areas are here divided into priority groups, high priority areas H, medium priority M and low priority L.

Each area is given priority according to the following table:

Value of usage	Sensitivity				
	L	L/M	M	M/H	H
L	L	L	L	L	L
L/M	L	L	L	L	M
M	L	L	M	M	M
M/H	M	M	M	H	H
H	M	M	H	H	H

In the tables in Chapter 5.9.4 where the areas are presented, priority group H is marked with three stars, group M with two stars and group L with one star.

Some of the outdoor recreational areas are only in use during summertime and for a great many of the areas the activity is at least higher in summer. For some shore types the self cleaning ability is so high that oil spilt in autumn may be eroded away before next summer season. Oils spill on these types of shore will therefore be less harmfull to recreation interests if the pollution happens during late autumn or winter. For the most sensitive sites the timing of a spill is of little importance since oil erosion will take many years (cf. chapter 5.2).

5.9.3 Political aims

This year the counties prepare their new county plans for the period 1988-91.

At the time of our reporting, only Nordland county had a draft of their county-plan available. For the other counties we have been in personal contact with local county authorities (Nord-Trøndelag fylkeskommune: Vidar Natvig, Sør-Trøndelag fylkeskommune: Tore Kiste).

The draft of the Nordland county plan 1988-91 states that two regions in the county's costal zone are given priority to tourism. These are the Lofoten/Vesterålen region and The South-Helgeland. The draft claims that outdoor recreation areas near to population centers should be given higher preference.

According to contact with the Nord-Trøndelag county authorities the outer Namdal region, that means Leka, Nærøy and Vikna municipalities, are the most important regions with respect to human usage, recreation, and tourism. The information on this item was, however, given in a general manner.

According to the Sør-Trøndelag county authority the coastal zone from Fosen to Frøya is given priority as a tourist area.

The political priorities will be taken into account in the conclusion for section 5.9, but not in the tables and in the maps.

5.9.4 Sites of importance to human usage

All areas of interest to human usage in Nordland, Nord-Trøndelag and Sør-Trøndelag counties are listed in tables 5.9.1 to 5.9.3. The sites are numbered within each county. Numbers are given along the coastline from north to south.

It is important to note that all values L (low), M (medium) or H (high) given in this chapter are estimates made from available information without visiting any of the sites and that some of the available data may be general and sometimes inaccurrate.

For some of the municipalities, existing data gives little information on the value of usage. Mostly the value is said to be local or regional with few distinctions. That means, for some municipalities the value M (medium) for value of usage, is seldom used.

All areas of interest to human usage are also indicated on figures 5.9.1 to 5.9.3. Sites given high or medium priority are given numbers corresponding to the numbers in the tables 5.9.1 to 5.9.3

Table 5.9.1. **NORDLAND HUMAN USAGE**

Andøy municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
1	Bleikstranden	Recreation area	L/M	H	**
2	Otervika	Recreation area	L/M	M/H	*
3	Høyvika	Recreation area	M	M/H	**
4	Børvågen	Recreation area	L/M	M/H	*
5	Fløberget-Børvågsholmen	Recreation area	H	L	**
6	North of Mele	Recreation area	H	H	***
7	Gavlneset	Recreation area	L/M	M/H	*
8	Tranesvågen	Recreation area	L	M/H	*
9	Buksnesfjord	Recreation area	M	M/H	**
10	Forfjord	Recreation area	L	M/H	*

Øksnes municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
11	Meløysanden	Recreation, bathing	H	M/H	***
12	Sandvika	Recreation, bathing	H	M/H	***
13	Stengelvågsand	Recreation, bathing	H	M/H	***
14	Skogsøya east	Recreation, touring	H	L/M	**
15	Sommerøya	Recreation area	H	M/H	***
16	Staven area	Recreation area	L	L/M	*
17	Indre Auenfj.	Touring, bathing	H	L/M	**
18	Ryggpollen-Aunefjorden	Touring, bathing	M	L/M	*
19	Nærøya	Recreation area	L	L/M	*
20	Tindsøya	Recreation area	L	L	*

Bø municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
21	Møkland-Utskår	Recreation area	L	L/M	*
22	Malnessanden	Recreation, bathing	H	M	***
23	Åsanfjord-Eidet	Recreation area	L	M	*
24	Vikan	Recreation area	L	M	*
25	Søberg-Skarpvågen	Recreation area	L	M	*
26	Fjærvoll-Føre	Recreation, bathing	H	M	***
27	Gauk-Værøy	Recreation area	L	L	*
28	Finøya	Recreation area	L	L	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.1. **NORDLAND HUMAN USAGE** (Continuing)

Sortland municipality: No recreation areas registrated.

Hadsel municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
29	Skjærvøyene	Daytripping, fishing	M	L	*
30	Aarneset	Bathing	H	L/M	**
31	Børøen	Bathing	L	M	*
33	Sandøya	Bathing	L	M/H	*
34	Haugneset	Recreation aera	L	L	*
35	Taenviken	Bathing, daytripping	H	M	***
36	Fiskefjorden	Fishing	L	M/H	*
37	Lonkanfjorden	Recreation	L	M/H	*
38	Raftsund incl. Trollfjorden Ingelsfjord	Recreation	L	L/M	*
39	Falkfjorden	Fishing, recreation	L	L/M	*
40	Fiskebøl	Bathing, daytripping	H	M/H	***
41	Grunnfør Grunnførfjord	Recreation aera	L	M/H	*

Vågan municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
42	Kvitsand (bay)	Recreation aera	L	M	*
43	Sandøen	Recreation aera	L	L	*
44	Kjepsøen	Recreation aera	L	L	*
45	Husvaag	Recreation aera	L	M/H	*
46	Storvaagen-Helleodden	Recreation aera	M	L	*
47	Bremerholmen-Seingsdraget	Recreation aera	L	L/M	*
48	Rørvik (bay)	Recreation aera	L	M	*
49	Sletten	Recreation aera	L	M/H	*
50	Laukvik-Spongskjæret	Recreation aera	L	L	*
51	Vinjeviken	Recreation aera	L	H	*
52	Hov	Recreation aera	L	L/M	*

Vestvågøy municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
53	Haugen	Recreation aera	L	M	*
54	Høynes-Naustholmen	Recreation aera	L	M	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.1. **NORDLAND HUMAN USAGE** (Continuing)

Vestvågøy municipality (continuing)

Nr	Name	Type of usage	Uservalue	Sens.	Priority
55	Borgvær	Recreation aera	L	L	*
56	Eggum-Utdalsvannet	Daytripping	M/H	M	**
57	Unstadbukta	Recreation aera	H	M/H	***
58	Vikspollen	Recreation aera	L	M/H	*
59	Flesa area	Recreation aera	L	L	*
60	Sandøen area	Recreation aera	L	L/M	*
61	Valberg area	Recreation aera	L	L/M	*
62	Sandviksnesset	Recreation aera	L	L/M	*
63	Eidsholmen	Recreation aera	L	L/M	*
64	Brandholmen	Recreation aera	M	L	*
65	Buksnes east	Recreation aera	L	L/M	*
66	Kjeøen	Recreation aera	L	L	*
67	Balstad	Recreation aera	L	L/M	*

Flakstad municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
68	Nesslandsheia	Recreation aera	L	L	*
69	Bø-Kilan	Recreation, bathing	H	H	***
70	Flakstad	Recreation aera	H	M/H	***
71	Ramberg	Recreation, bathing	H	M/H	***
72	Selfjorden	Touring	M	M	**

Moskenes municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
73	Moskenesøy E	Recreation aera	M/H	L/H	**
74	Horseid	Recreation aera	M/H	M/H	***
75	Bunes	Recreation aera	M/H	H	***
76	Vorfjorden	Recreation aera	L	L/M	*
77	Veineset	Recreation aera	L	L/M	*
78	Djupfjorden	Recreation aera	L	L/M	*
79	Bogen	Recreation aera	L	L	*
80	Å	Recreation aera	L	M	*
81	Tuv	Recreation aera	L	M	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.1. **NORDLAND HUMAN USAGE** (Continuing)

Værøy municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
82	Nordlandshagen	Recreation aera	L	M	*
83	Sørlandshagen	Recreation aera	H	M	***
84	Sanden	Recreation aera	L	M	*
85	Mostadbukta	Recreation aera	L	M	*

Røst municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
86	Øiran	Recreation aera	L	L	*
87	Sandøerne	Recreation aera	L	L	*
88	Vedøya north	Recreation aera	L	L	*
89	Storfjellet	Recreation aera	L	L	*
90	Buvær	Recreation aera	L	L	*

Lødingen municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
91	Storhaugneset-Hamnes	Recreation area	L	L/M	*
92	Vikpollen	Recreation area	L	L/M	*
93	Sommerset(bay)	Recreation area	L	L/M	*
94	Lakselvviken	Recreation area	L	M	*
95	Husfjorden-Brynjolfslåten	Recreation area	L	M	*
96	Halvardsøen	Recreation area	L	L	*
97	Islands from eastern border to Alpøen	Recreation area	L	L	*
98	Vika-Silsjøen	Recreation area	L	L/M	*
99	Hesten-Storose	Recreation area	L	M	*
100	Hauksfjorden	Recreation area	L	L/M	*
101	Eriksfjorden	Recreation area	L	L	*
102	Indrefjorden	Recreation area	L	M/H	*
103	Rotværet	Recreation area	L	L	*
104	Breidablikk-Kaaringen	Recreation area	L	M/H	*
105	From border to Kistholmen	Recreation area	L	M	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.1. **NORDLAND HUMAN USAGE** (Continuing)

Tjeldsund municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
105	Stakksvoll	Recreation area	L	M/H	*
106	Klungnes-Ballstad	Recreation area	L	M/H	*
107	Sandsbukta	Recreation area	L	M/H	*
108	Valvågen	Recreation area	L	M	*
109	Kierfjorden-Våjebukta	Recreation area	L	L/M	*
110	Russvik	Recreation area	L	M	*
111	Breiviken	Recreation area	L	M/H	*
112	Spanbogstraume	Recreation area	L	M/H	*
113	Hunvollen incl. islands	Recreation area	L	M	*

Evenes municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
114	Innerholmen Ytterholmen	Recreation, bathing	L	L	*
115	Evenesvika	Recreation, bathing	L	M/H	*
116	Skogøen	Recreation, bathing	L	L/M	*
117	Lerosen-Dragvika	Recreation, bathing	L	M/H	*
118	Lenvika-Kobbsteinneset	Recreation, bathing	L	M/H	*

Narvik municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
119	Veggen-Aspneset	Recreation area	L	L	*
120	Herjangholmen-Bjerkvik	Recreation area	L	L/M	*
121	Ornesvika	Recreation, bathing	L	L	*
122	Lillevik	Recreation area	L	L	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.1. **NORDLAND HUMAN USAGE** (Continuing)

Ballangen municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
123	Arnes	Recreation area	L	M/H	*
124	Hesjholmen	Recreation area	L	M/H	*
125	Djupvik east	Recreation area	L	M/H	*
126	Punkvikneset	Recreation area	L	L/M	*
127	Kjeldebotn	Recreation area	L	M/H	*
128	Hamnesholmen	Recreation area	L	L	*
129	Vargfjorden	Recreation area	L	L/M	*
130	Storvika-Slåttvika	Recreation area	L	L/M	*
131	Kobbvik	Recreation, camping	L	L/M	*
132	Sandvikneset	Recreation area	L	M	*
133	Kjerringvika	Recreation area	L	M/H	*
134	Henriknesbukta	Recreation area	L	M	*
	Vallebukta	Recreation area	L	M	*
135	Eastern border to Kobbhola	Recreation area	L	M	*

Tysfjord municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
136	Straumpollen	Recreation, touring	M	M	**
137	Fredagsvik-Kobbvik	Daytripping, bathing	L	L/M	*
138	Hestvik	Recreation area	L	L	*
139	Inner part of Stefjord	Touring	M	L/M	*
140	Munnfjorden	Touring	L	L/M	*
141	Ulvøen	Recreation area	L	L	*
142	Botnøya	Recreation area	L	L	*
143	Sandvika-Herrøyvika	Bathing, touring	L	M	*

Hamarøy municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
144	Stordjupet Presteidfjord	Recreation area	L	L	*
145	Brennvik	Recreation area	L	M	*
146	Strømhavn-Trinnøya	Recreation area	L	M	*
147	Dalsvær	Recreation area	M	M	***
148	Skutvik-Utåkir	Recreation area	L	L/M	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.1. **NORDLAND HUMAN USAGE** (Continuing)

Steigen municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
149	Bøsanden	Recreation, bathing	L	M/H	*
150	Steinberget	Daytripping	L	L/M	*
151	Islands outs. Våg-Steinberge	Recreation, bathing	L	L	*
152	Vikstømmen	Recreation, fishing	L	L	*
153	Liland	Bathing, fishing	L	M	*
154	Oksholmene	Touring, fishing	L	L/M	*
155	Grøtøen etc.	Recreation area	L	L	*
156	Islands outs. Nordskot	Recreation, bathing	L	L	*
157	Myklebostad	Recreation area	L	L	*
158	Islands outs. Helnessund	Recreation, bathing	L	L	*
159	Feøya	Recreation, bathing	L	L	*
160	Brennviksanden	Recreation, bathing	H	M/H	***
161	Storsanden Flekkos	Recreation, bathing	L	M	*
162	Balkjosen	Daytripping, fishing	L	M	*
163	Hartøy north incl. islands	Recreation, bathing	H	L/M	**

Sørfold municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
164	Aspvika	Touring, bathing	L	M	*

Bodø municipality

Nr.	Name	Type of usage	Uservalue	Sens.	Priority
165	Lysvik	Recreation area	L	M	*
166	Mistfjorden	Recreation area	M	L/M	*
167	Mjelde	Recreation area	L	M	*
168	Mulstrand	Recreation area	L	M	*
169	Skau	Recreation area	L	M/H	*
170	Middagdalfjell	Recreation area	L	M/H	*
171	Vågøya	Recreation area	L	L	*
172	Geitvågen	Bathing, camping	L	M	*
173	Ansvika-Løp	Recreation area	L	M	*
174	Bratten	Recreation area	L	L	*
175	Stor-Hjertøya	Recreation area	L	L	*
176	Steinsvær	Recreation area	L	l	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.1. **NORDLAND HUMAN USAGE** (Continuing)

Bodø municipality (continuing)

Nr	Name	Type of usage	Uservalue	Sens.	Priority
177	Bodøsjøen	Camping	L	M	*
178	Fenes	Recreation, fishing	L	L	*
179	Tverlandet	Recreation area	M	M	**
180	Saltstraumen	Camping, fishing	L	L	*
181	Skagen	Recreation area	L	L	*
182	Strømøya Seines	Recreation area	L	M	*

Gildeskål municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
183	Ravik	Recreation, bathing	L	M/H	*
184	Breivik-Vågosen	Recreation, bathing	L	M/H	*
185	Fleinvær	Recreation area	L	L	*
186	Laukholmene	Recreation area	L	L	*
187	Fugløya	Recreation area	L	L	*
188	Noviken	Recreation area	L	M/H	*
189	Storviken	Recreation area	L	H	*

Meløy municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
190	Teksmona	Recreation, bathing	L	L	*
191	Guldholmen-Bremneset	Recreation, bathing	L	M	*
192	Gjersodden-Sildvik	Recreation, bathing	H	M	***
193	Eidebukta	Recreation, bathing	L	L/M	*
194	Sandåbukta	Recreation, bathing	L	M	*
195	Hestøen	Recreation, bathing	L	L/M	*
196	Valvær	Recreation area	L	L	*

Rødøy municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
197	Nordfjorden	Recreation area	H	L	**

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.1. **NORDLAND HUMAN USAGE** (Continuing)

Træna municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
198	Dørvær	Recreation area	L	L	*
199	Torvær,Mårøya	Recreation area	L	L	*
200	Røsøyan	Recreation area	L	L	*
201	Sanna (outer)	Recreation area	H	L	**
202	Træna lighthouse	Recreation area	L	L	*

Lurøy municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
203	Sørnesvågen	Recreation area	L	M	*
204	Tonnes	Bathing, camping	L	M/H	*
205	Arnsand	Recreation, bathing	L	M/H	*
206	Between outer & inner Kvarø	Recreation area	L	M	*
207	Hagen, Lurøyhavnen	Recreation area	L	L/M	*
208	Stokksviken	Recreation area	L	L/M	*
209	Nøvika	Recreation, bathing	L	M	*
210	Lovund	Recreation area	H	M	***
211	Grønsvika	Recreation area	L	M	*
212	Selnes,Røytvik	Recreation area	H	L/M	**
213	Silapollen	Recreation area	M	M	**

Nesna municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
214	Islands north of Tomma	Daytripping	M	L/M	*
215	Finnvika	Recreation area	H	M	***
216	Rørholmen-Kiløy	Recreation area	L	M/H	*
217	Strenggjerdet-Hjartøyene	Recreation area	L	M	*
218	Alsøya	Recreation area	H	M	***
219	Handsten-Villa	Recreation area	M	M	**
220	Breivikskjeret Fagerlibukten	Recreation area	L	L/M	*
221	Juviken-Skagaskjæret	Recreation area	L	L	*
222	Longset	Recreation area	M	M/H	**

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.1. **NORDLAND HUMAN USAGE** (Continuing)

Nesna municipality (continuing)

Nr	Name	Type of usage	Uservalue	Sens.	Priority
223	Nordneset-Sletsland	Recreation area	L	L	*
224	Hamarøysanden	Recreation area	M	M/H	**
225	Nordbostad	Recreation area	L	M/H	*
226	Hugla north	Recreation area	L	L/M	*
227	Nordsjøbukta	Recreation area	M	L/M	*
228	Huglneset Fagerneset	Recreation area	M	M	**

Leirfjord municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
229	Leirfjordbotn	Recreation area	L	H	*
230	Bruneset Forneset		L	L/M	*

Dønna municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
231	Breiviken	Recreation area	L	M/H	*
232	Tranøy,Ormsøy, Lovøy	Recreation area	L	L	*

Herøy municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
233	Kiperviken	Recreation area	L	L	*
234	Islands outs. Øksingen	Recreation area	L	L	*
235	Bay west in Herøysund	Recreation area	L	L	*
236	Einarsøy-Slimskjærene	Recreation area	L	L	*
237	Bay near Hestholmen	Recreation area	L	L	*
238	Dragneset-Kvikleirøyene	Recreation area	L	L	*
239	Hjartøya	Recreation area	L	L	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.1. **NORDLAND HUMAN USAGE** (Continuing)

Alstahaug municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
240	Storøy,Langøy, Lamholmen	Recreation area	L	L	*
241	Hornesodden	Recreation area	L	L	*
242	Noviksjøen	Recreation area	L	M	*
243	Altern, east of Akerøy	Recreation area	L	L	*
244	Alstahaug-Haugneset	Recreation area	L	M	*
245	Offersø north	Recreation area	M	M	**
246	Tangen-Store Lamholme	Recreation area	L	L	*
247	Marnøy-Røsøyholmene	Recreation area	L	L/M	*
248	Halsanfjorden	Recreation area	L	L	*

Vega municipality: No recreation area registrated

Vevelstad municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
249	Aunvågen-Almosen	Recreation area	L	L/M	*
250	Ausa-Strandbukten	Recreation area	L	L	*
251	Havnøya east	Recreation area	L	M/H	*
252	Oddøy, Gråøy, Rørøy etc.	Recreation area	L	L	*
253	Hamnsundet	Recreation area	H	L/M	**

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.1. **NORDLAND HUMAN USAGE** (Countinuing)

Brønnøy municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
254	Lillebørja	Daytripping	L	L	*
255	Okfjord	Daytripping	L	L	*
256	Storfjord	Daytripping	L	L	*
257	Storebørja Lillebørja	Recreation area	L	L	*
258	Sandvik-Drogsøya	Recreation area	L	L/M	*
259	Strømøya	Camping,bathing,fish.	L/M	L	*
260	Utstabbvik	Recreation, bathing	L	M	*
261	Brønnøysund	Recreation, bathing	L	L/M	*
262	Klubben	Recreation aera	L	L	*
263	Sauren	Daytripping	L	L/M	*
264	Outer part of Torget	Daytripping	L	L/M	*
265	Torget	Recreation area	H	M	***

Sømna municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
266	Sømnesø-Mardal	Recreation area	H	M/H	***

Bindal municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
267	Ursfj.Bindefj. Tosenfjorden	Recreation area	L	M	*
268	Repphullet	Touring, fishing	L	M	*
269	Osan	Recreation, bathing	L	M/H	*
270	Vikestadvågen	Recreation, bathing	L	M/H	*
271	Solstad-Lysfjord	Recreation area	H	M/H	***

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.2. **NORD-TRØNDELAG HUMAN USAGE**

Leka municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
1	Årdalsanden	Recreation, bathing	M	M	**
2	Solumøyene	Recreation,daytripping	L	L	*
3	Leknesøya	Recreation,daytripping	L	L	*
4	Lundsvika	Recreation, touring	L	M	*
5	Sandhalsen	Recreation, touring	L	L	*

Nærøy municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
6	Dolma	Daytripping,bath.,fish	L	L	*
7	Risværet	Daytripping,bath.,fish	M/H	L	**
8	Gjeringa	Daytripping,bath.,fish	M/H	L/M	**
9	Ramfjordbotn	Daytripping, fishing	L	L	*
10	Sørsalten	Daytripping,bath.,fish	H	L	**
11	At Ottersøy bridges	Fishing	L/M	L	*
12	Gjersengvika	Daytripping, bathing	L	L	*
13	Skjåbukta	Daytripping, bathing	L	M/H	*
14	Lille Bjørk-neset	Daytripping, bathing	L	L	*
15	Gammelgårds-fjæra	Bathing	L	M	*
16	Lundringsvika	Daytripping,bath.,fish	H	L	**
17	Oterholmen				
18	Nærøya south	Daytripping,bath.,fish	H	M	***
	Korsholmen	Daytripping,bath.,fish	H	L	**
19	Småværet	Daytripping,bath.,fish	H	L	**
20	Rossøystraumen Rossøyfjorden	Daytripping	H	L	**
21	Vågsvågen	Daytripping, bathing	L/M	M/H	*
22	Varøy	Daytripping, bathing	L/M		
23	Juvika	Daytripping, bathing	L/M	L	*
24	Steinvika-Abelvær	Bathing	L/M	M/H	*
25	Kjeksvika	Bathing, touring	L/M	M/H	*
26	Klugset	Daytripping, bathing	L	L/M	*
27	Laugvågen-Hestvika	Daytripping, bathing	L	L	*
28	Korsneset	Fishing, daytripping	L	L	*
29	Langbogan Indre Folda	Bathing	L	L	*
30	Kvisten	Daytripping,bath.,fish	L/M	L	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.2. **NORD-TRØNDELAG HUMAN USAGE** (Continuing)

Nærøy municipality (continuing)

Nr	Name	Type of usage	Uservalue	Sens.	Priority
31	Stadsøya etc.	Daytripping,bath.,fish	L/M	L	*
32	Langvassbukta in Oppløyfj.	Bathing	L	M	*
33	Islands in Oppløyfjord	Daytripping,bath.,fish	L/M	L	*
34	Fjærangen	Daytripping,bath.,fish	H	L/M	**

Vikna municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
37	Sandvika Eiternes	Bathing	L		
38	Kråkøya	Daytripping,bath.,fish	L	L	*
39	Hansvika	Recreation, bathing	L/M	L/M	*
40	Hasfjordhopen	Daytripping, fishing	H	L	**
41	Ramstadkleiva	Daytripping,bath.,fish	H	L/M	**
42	Åforøya	Recreation, fishing	L	L	*
43	Belseng area	Daytripping, bathing	L	L	*
44	Kjønsøyvågen	Recreation, bathing	L/M	L/M	*
45	Garstad area	Fishing, touring	L/M	L/M	*
46	Svinøya	Daytripping, fishing	L/M	L/M	*
47	Dragsprøyta	Recreation, bathing	L/M	L	*
48	Steinfjorden	Recreation, bathing	L/M	L	*
49	Åkvika	Recreation, bathing	L/M	L/M	*
50	Ryemsjøen	Daytripping, bathing	M	L	*
51	Sørgjeslingen	Daytripping,bath.,fish	L/M	L	*

Fosnes municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
52	Leirvika-Naustneset	Recreation	L	L	*
53	Kuholmen-Skreddersnes	Receation	L	L	*
54	Måsøya,Skogøya Nordøya	Recreation	L	L	*
55	Steinene	Recreation	L	L	*
56	Langskjæret Moflesa	Recreation	L	L	*
57	Hovsodden	Recreation	L	L	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.2. **NORD-TRØNDELAG HUMAN USAGE** (Continuing)

Fosnes municipality (continuing)

Nr	Name	Type of usage	Uservalue	Sens.	Priority
58	Elvebakken Haugtun	Recreation	L	L	*
59	Biskopvikstr.	Receation	L	L	*
60	Nufsfjorden	Receation	L	L	*
61	Nordsundet	Recreation,daytripping	M	L	*

Namsos municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
63	Blikengfjorden	Daytripping	M	M	**
64	Heimdalbotn	Daytripping	M	M	**
65	Ganesodden	Recreation	L	M	*
66	Lauvøyfjorden	Daytripping	M	M	**
67	Løvøy	Daytripping	L	L	*
68	Lyngholmen etc	Daytripping	L	L	*
69	Barøya, Sauøya Finnangerøya	Daytripping	L	L/M	*
70	Tømmervika	Bathing, camping	M	H	**
71	Aglen area	Bathing, camping	L	L/M	*
72	Altøya	Daytripping	L	L	*
73	Sandvik Bromsnesset	Daytripping	L	M	*
74	Sør-Namsen	Daytripping	M	L	*
75	Hoddøystranda	Bathing, touring	L	M/H	*
76	Gåsøyene	Bathing, touring	L	L	*
77	Brandøen	Bathing, touring	L	L	*
78	North of Gullholmstrand	Recreation	L	L/M	*
79	Gullholmstrand Gullholmen	Bathing	M	M	**
80	Mærraneset	Bathing, touring	M	M/H	**
81	Høknesøra	Bathing,camping,tour	M	H	**
82	Storvika	Recreation	L	M/H	*
83	Prestvika	Bathing	L/M	M	*
84	Oldervika Kvaholmen	Touring	L/M	M	*
85	Kvarvøya	Bathing, touring	L	L	*
86	Breidvika Oldervika	Recreation	L	M	*
87	Lyngen area	Daytripping	M	L	*
88	Brenvikholmen Fjærholmen etc	Daytripping	L	L/M	*
89	Kalvvika	Recreation	L/M	M	*
90	Skavika	Bathing	L/M	L	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.2. **NORD-TRØNDELAG HUMAN USAGE** (Continuing)

Namdalseid municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
91	Lyngenfjord--botn, Sjøåsen	Bathing	L/M	M/H	*
92	Ertsbukta	Recreation	L	M/H	*
93	Skjerpøya	Touring	M	M/H	**
94	Sundsvalen	Bathing, daytripping	M	L	*
95	Tøtdalsstrand	Bathing	L	L/M	*
96	Langstranda	Bathing, daytripping	L/M	M/H	*
97	Ledangsvalen	Bathing, daytripping	L/M	M/H	*

Flatanger municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
98	Hestvika-Urdvika	Bathing, daytripping	L	M	*
99	Fugløya	Recreation area	L	L	*
100	Steinsøya	Recreation area	L	L/M	*
101	Havstein west	Bathing, daytripping	L	M	*
102	Knotten Bordvikodden	Recreation area	L	L	*
103	Einan-Knottbukta	Bathing, daytripping	L	L	*
104	Vågan	Bathing	L/M	M	*
105	Ytre Bardøya	Recreation area	L	L	*
106	Lauvøya north	Bathing, daytripping	L	M	*
107	Kvernøya	Bathing, daytripping	L	L/M	*
108	Ellingen, Ellingsråsa N	Daytripping, bathing	L	M	*
109	Lyngvær	Daytripping, bathing	L	L	*
110	Halmøya	Daytripping, bathing	L	M/H	*
111	Stolavika	Receation area	L	L	*
112	Gladsøya	Daytripping, bathing	L/M	M	*
113	Vannavika	Recreation area	L	L/M	*
114	Laukvika	Daytripping, bathing	L	L	*
115	Selsvikodden	Recreation aera	L	L	*
116	Kvaløya	Daytripping, bathing	L	L/M	*
117	Estenvika	Daytripping, bathing	L	M	*
118	Langneset	Recreation aera	L	L	*
119	Jøssundøya	Recreation aera	L	L	*
120	Kløvika,Ska--vika, Øyvika	Daytripping, bathing	L	L/M	*
121	Hasvåg	Daytripping, bathing	L	M	*
122	Hornesholmen to Rugholmen	Daytripping, bathing	L/M	L	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.2. **NORD-TRØNDELAG HUMAN USAGE** (Continuing)

Flatanger kommmune (continuing)

Nr	Name	Type of usage	Uservalue	Sens.	Priority
123	Oksbåsan Bølstranda	Daytripping, bathing	L	M	*
124	Seljevika	Recreation aera	L	M	*

Leksvik municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
125	Arnfjæra Aknesfjæra	Bathing	H	M/H	***
126	Sæterbukta	Bathing	L/M	M/H	*
127	Hindremsbukta	Bathing	L/M	M/H	*
128	Grandefjæra	Bathing	H	M/H	***
129	Rønningen	Bathing	H	M/H	***
130	Innerelva,Kroa	Marina	L/M	M/H	*
131	Hjellrupfjæra	Bathing	L/M	M/H	*
132	Sandviksfjæra	Bathing	L/M	M/H	*

Mosvik kommmune

Nr	Name	Type of usage	Uservalue	Sens.	Priority
133	Slipersjøen	Daytripping, bathing	H	M	***
134	Saltvikhamn	Recreation aera	L	L	*
135	Kjerringvik Brevik	Bathing, fishing	L/M	L	*

Inderøya municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
136	Undersåker	Bathing	L/M	M/H	*
137	Sundssanden	Bathing, camping	H	M	***
138	Høsholmene	Bathing	H	L/M	**
139	Koabjørga	Bathing, camping	H	M	***

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.2. **NORD-TRØNDELAG HUMAN USAGE** (Continuing)

Verdal municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
140	Tronestangen	Bathing, touring	L/M	M	*
141	Havfrua	Bathing	L	M	*
142	Ørin-Bergsfætten	Recreation, bathing	M	M/H	**

Levanger municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
143	Rinnleiret	Recreation aera	M/H	H	***
144	Skånestangen	Recreation, bathing	H	M	***
145	Alfnesfjæra-Håalandet	Recreation, bathing	H	M	***
146	Tangen	Recreation, bathing	L/M	H	**
147	Hestøya	Daytripping, bathing	L/M	M	*
148	Kristivik-Finnsvik	Recreation, bathing	L/M	L	*
149	Falstadbukta Strandholmen	Bathing	L	H	*
150	Barstadbukta	Recreation, bathing	L/M	H	**
151	Hokstad	Recreation, bathing	L/M	M	*
152	Vandviksfjæra	Recreation, bathing	H	M/H	***

Frosta municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
153	Åsholmen	Camping, bathing	M	M	**
154	Aatlobukta	Bathing	L	M/H	*
155	Fånesbukta	Bathing	L	M/H	*
156	Ordsandbukta	Bathing	L	M	*
157	Brevika	Recreation aera	L	M	*
158	Småland	Recreation aera	L	M	*
159	Tautra	Recreation aera	L	H	*
160	Gullberget-Hynne	Camping, bathing	H	M	***
161	Hammeren-Logstein	Camping, bathing	H	M	***
162	Laberget Manneset	Bathing	L	M	*
163	Kvitsandvik Moksneslia	Bathing	L	L/M	*
164	Korsneset	Bathing	L	L	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.2. **NORD-TRØNDELAG HUMAN USAGE** (Continuing)

Stjørdal municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
165	Paradisbukta	Camping, bathing	M	M	**
166	Saltøya	Bathing	M	M	**
167	Steinvikholmen	Bathing	H	M	***
168	Fiskvik	Recreation aera	L	M	*
169	Vingebukta	Camping, bathing	M	M/H	**
170	Vingebukta-Kleivan	Recreation aera	L	M	*
171	Vikaune-Storvika	Recreation aera	L	M	*
172	Storvika	Camping, bathing	H	L	**
173	Langøra	Bathing	M	M/H	**
174	Hellstranda	Bathing	L	M	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.3. **SØR-TRØNDELAG HUMAN USAGE**

Osen municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
1	Mårviken	Bathing, fine nature	L	M/H	*
2	Drageid-Holand	Public recration area	L/M	M	*
3	Sve/Sandvik	Bathing, fine nature	L	L/M	*
4	Hellevika	Bathing, fine nature	L	L	*
5	Håmannvika	Bathing	L	M	*
6	Ørin	Camping, bathing	H	M	***
7	Forøya	Public bathing place	H	M	***
8	Pervika	Bathing	L	M	*
9	Ursørodden	Sportsfishing	L	M	*

Roan municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
10	Vikaunet	Bathing beach	L	L/M	*
11	Lillevika	Bathing	L	M	*
12	Vettavik	Bathing	L	L/M	*
13	Nordvika	Bathing beach	L	L/M	*
14	Sumstad	Bathing beaches	L	L/M	*
15	Utrosjøen	Bay, bathing	L	L/M	*
16	Vika	Bathing	L	M	*
17	Mavika	Bathing	L	M	*

Åfjord municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
18	Hosbakvika Holmen,Fasth.	Recreation area	L	H	*
19	Hosensand	Bathing	M/H	L/M	**
20	Straumen	Recreation area	L	M	*
21	Bay SW Linesøy	Recreation area	L	L/H	*
22	Bay at Rovik	Recreation area	L	L/H	*
23	Selsettangen	Public bathing area	H	H	***
24	Saltnes-Markafjord	Recreation area	L	H	*
25	Drageid	Bathing	L	L/M	*
26	Jovika	Bathing	L	M	*
27	Steinkjerbukta	Recreation area	L	L/M	*
28	East at Lauvøy	Recreation area	L	M	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.3. **SØR-TRØNDELAG HUMAN USAGE** (Continuing)

Bjugn municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
29	Selnes	Bathing	L	M	*
30	Tiltremsneset	Sportsfishing	L	L	*
31	Hulkilen	Daytripping,bath.,fish	M	L/M	**
32	Asserøy-Asserstrand	Bathing	M	M	**
33	Koet, outlet	Sportsfishing	L	L	*
34	Risvika	Beach,bathing,fishing	H	M/H	***
35	Mebostad	Public beach, bathing	L/M	M	*
36	Stallvika-Sætvika		M	M	**
37	Kipnes-Brandvk		M	L/M	*

Rissa municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
38	Vorpvikan-Harbaktangen	Bathing	L	M	*
39	Pevika	Public recreation area	H	L	**
40	Vestvikan	Bathing	H	M/H	***
41	Matneset	Bathing, recreation	L	L	*
42	Hasselvika	Bathing, recreation	L	M	*
43	Sjursvika	Bathing	L	M	*
44	Årlottneset	Bathing	L/M	L	*
45	Galgeneset	Bathing	L	L	*
46	Langsand-Uddu	Bathing,	H	H	***
47	Kvithyll	Bathing	L	M/H	*
48	Storneset	Bathing	L	M	*
49	Prestbukta	Bathing	M	M/H	**

Melhus municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
50	Gaulosen	Recreation, bathing	M	H	***
51	Øysand	Recreation, bathing	H	M/H	***

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.3. **SØR-TRØNDELAG HUMAN USAGE** (Continuing)

Skaun municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
52	Borsøra-Eliløkken	Recreation, bathing	L	M	*
53	Eliløkken-Haukvik	Bathing	L	L	*
54	Viggjagrunnene	Bathing	L	M	*
55	Tråssavika	Camping, bathing	L/M	M/H	*
56	Grønlandskjær	Bathing	L	M	*

Ørlandet municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
57	Austrått	Bathing	H	M/H	***
58	Bruholmen	Recreation, bathing	H	M/H	***
59	Gartenberga	Recreation, bathing	L	M	*
60	Uthaug	Bathing	L	L	*
61	Holmen	Bathing	L	L	*
62	Flatnesfjæra	Bathing	L	M	*
63	Hovdetåa	Bathing	L	L	*

Orkdal municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
63	Rove-Råbygda	Bathing	L	M	*
65	Hylla	Bathing	H	M	***
66	Åstnebben	Bathing	H	M	***
67	Åstan-Solbakke	Bathing	L	M/H	*
68	Klomsten Geitstranda	Bathing	H	M	***
69	Måneskinnsvika Geitaneset	Recreation area	L	M	*

Agdenes municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
70	Ramnåsen Ingalsbukta		L	M	*
71	Tennelsbukta	Bathing	L	M/H	*
72	Berganeset		L	L	*
73	Størdalsbukta		L	M	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.3. **SØR-TRØNDELAG HUMAN USAGE** (Continuing)

Agdenes municipality (continuing)

Nr	Name	Type of usage	Uservalue	Sens.	Priority
74	Voptåa- Agdenes fyr	Bathing	H	M	***
75	Ystholmen	Bathing	L	L	*
76	Sandvika	Bathing	L	M	*
77	Rishaug	Recreation, bathing	L	M	*
78	Værnes kai	Recreation, bathing	H	M	***
79	Verrrafjorden	Bathing	L	M	*
80	Gravika		L	M	*

Snillfjord municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
81	Lineset	Bathing	L	L/M	*
82	Storøya- Åstfjorden	Recreation, bathing	L	L	*
83	Aunbugen	Daytripping, bathing	L	M	*
84	Flesvikbukta	Bathing	L	M/H	*
85	Selnesbugen	Bathing	L	M	*
86	Forrabukta	Bathing	L	M/H	*
87	Jamtøya	Public recreation	M	M	**
88	Malneset	Bathing	L	L	*

Hemne municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
89	Fitjavågen	Bathing	L	M/H	*
90	Bugaholmen	Bathing	L	L	*
91	Gjevik- Hagan	Bathing	H	M/H	***
92	Sagneset		L	L/M	*
93	Skograndbukta		L	M/H	*
93	Krokhammaren	Bathing	L	L	*
94	Røstøy- Magerøy-Marøy	Public area, daytripp.	H	M	***
95	Taftøysund	Bathing	L	L	*
96	Mistfjorden	Daytripping	H	L/M	**
97	Sørvågen	Bathing	L	M	*
98	Heimsvågen	Bathing	L	M	*
99	Åosen Midtøra	Bathing	L	M/H	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.3. **SØR-TRØNDELAG HUMAN USAGE** (Continuing)

Hitra municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
100	Ingeborgvik	Bathing	L	L	*
101	Aunøya	Public area, bathing	H	M	**
102	Bjørnavågen		L	L	*
103	Hestøyarea	Daytripping	L	L	*
104	Kjølsøya	Bathing	L	L	*
105	Storstraumen	Sportsfishing	L	L	*
106	Olø		L	L	*
107	Vågan north	Sportsfishing, bathing	L	L	*
108	Vettastraumen	Sportsfishing	L	L	*
109	Dolmsund	Recreationareas	L	L	*
110	Bispøyan	Daytripping	M	L	*
111	Saueøya	Bathing	L	L	*
112	Laugen	Bathing	L	L	*
113	Breivika	Public area, bathing	M	L	*
114	Lya	Bathing, fine nature	L	L	*
115	Kvernavika	Bathing	L	L	*
116	Vågan	Public area, bathing	M	M	**
117	Balnesbugen-Kalvhaugterna		L	M	*
118	Selnes-Hamna		L	L/M	*
119	Kvernavika-Hallarneset		L	M	*
120	Aunøya-Hestvik		L	M	*

Frøya municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
121	Værø, Inntian, Uttian	Daytripping	M	M	**
122	Storfjorden	Bathing	L	L	*
123	Stabben	Daytripping	L	L	*
124	Titran north	Bathing	H	L	**
125	Lyngværarea		L	L	*
126	Hestøy	Daytripping	L	L	*

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

Table 5.9.3. **SØR-TRØNDELAG HUMAN USAGE** (Continuing)

Trondheim municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
50	Gaulosen	Recreation, bathing	M	H	***
127	Byneset	Bathing, fine nature	L	M	*
128	Frøsetgrunnen	Sportsfishing	L	M	*
129	Flakkneset	Recreation, bathing	L	M	*
130	Flakk	Recreation, bathing	L	M	*
131	Brennbukta	Recreation, bathing	H	M	***
132	Munkholmen	Recreation,bath.,fish	H	L	**
133	Ladehamr.Devle	Recreation, bathing	M	L/M	*
134	Leangbukta	Recreation	M	M/H	**
135	Grilstadfjæra	Recreation, bathing	L	M	*
136	Ranheim	Recreation, bathing	L	L/M	*
137	Værebukta	Recreation, bathing	H	M/H	***

Malvik municipality

Nr	Name	Type of usage	Uservalue	Sens.	Priority
138	Hundhammeren	Recreation, bathing	L	L	*
139	Vikhamarskjær				
140	Vikhamarbukta	Recreation	H	M/H	***
141	Malvikbukta				
	Malvikodden	Recreation	M/H	M	**
142	Malvikodden-				
	Storsand	Camping, bathing	H	M/H	***
143	Midtsanden-				
	Rota	Recreation, bathing	H	M/H	***
144	Flatholmene	Recreation, bathing	H	L/M	**

Uservalue= Value of usage, Sens= Sensitivity, H=High, M=Medium, L=Low

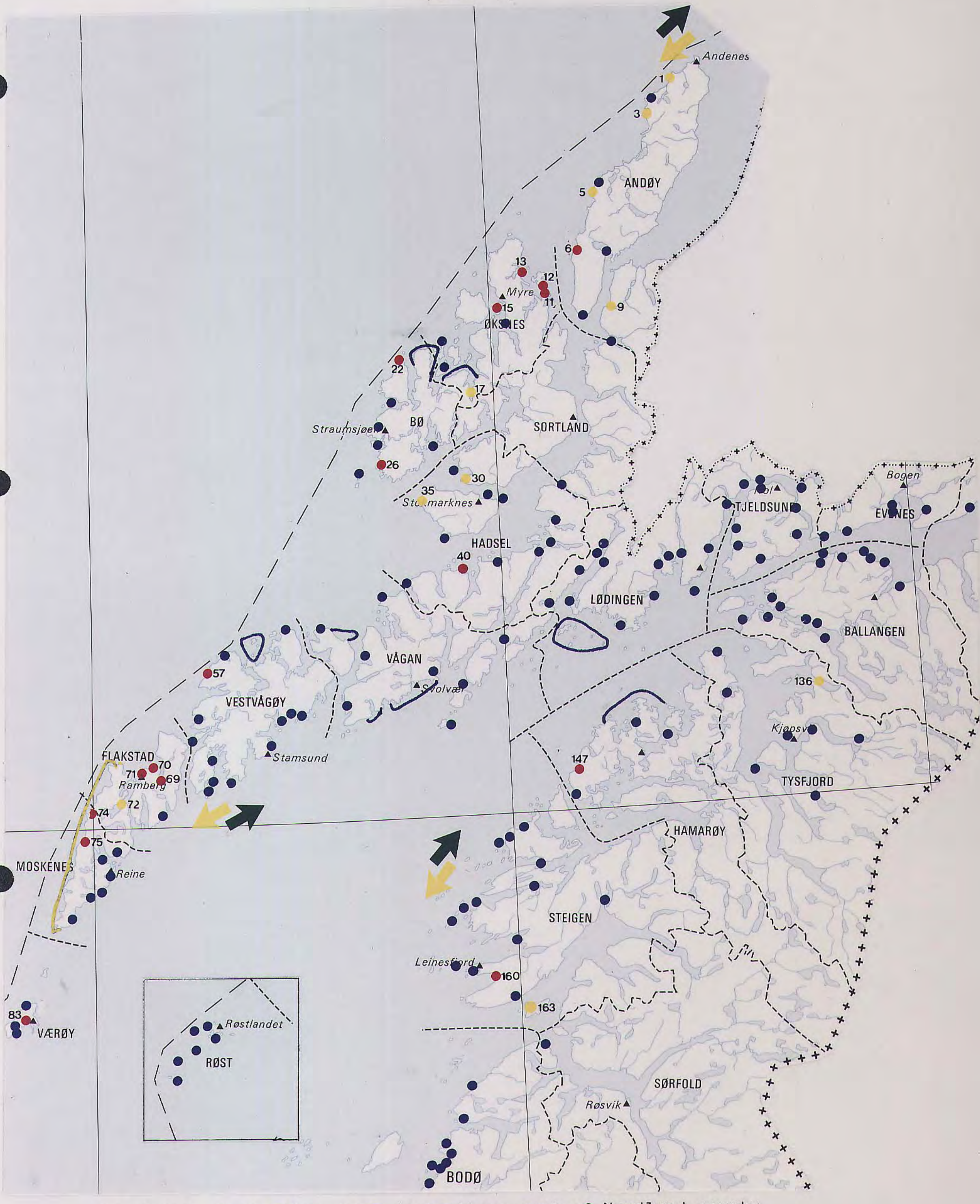


Fig 5.9.1 Recreation areas in northern part of Nordland county

Low priority area — Medium priority area

High priority area

Impact zones: high, medium, low.

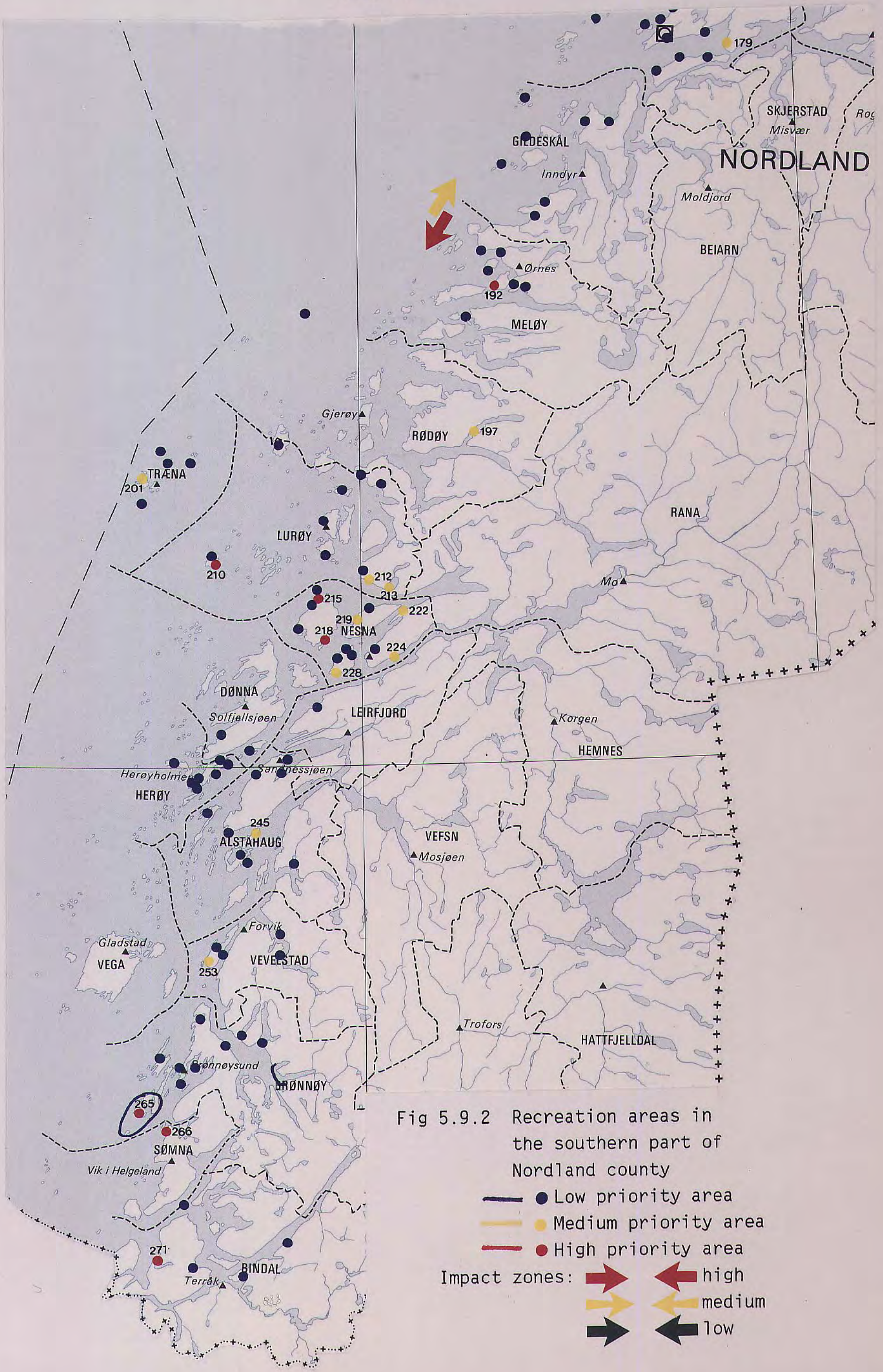


Fig 5.9.2 Recreation areas in the southern part of Nordland county

- Low priority area
- Medium priority area
- High priority area

Impact zones: high, medium, low

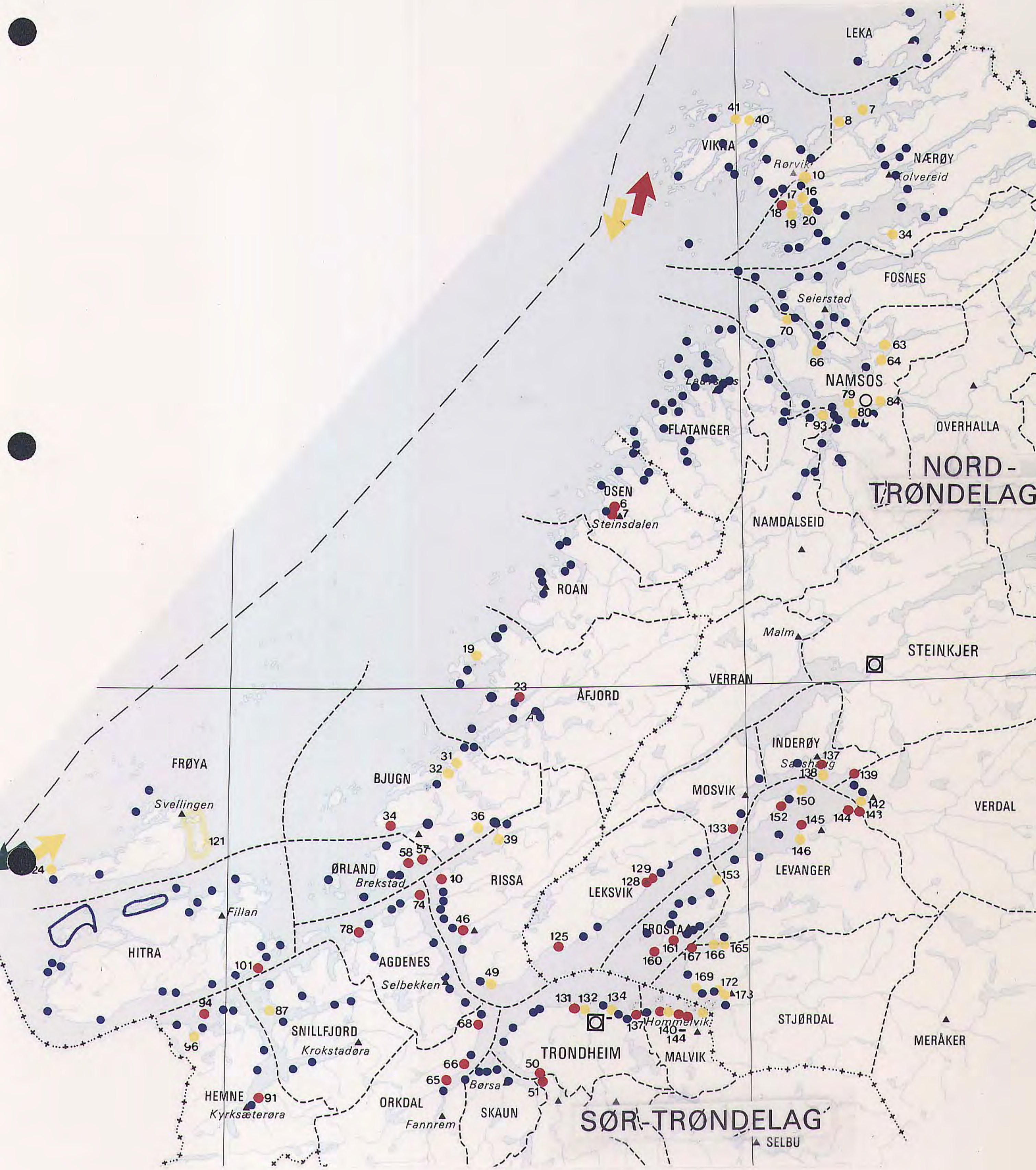


Fig 5.9.3 Recreation areas in Sør- and Nord-Trøndelag counties

● Low priority area ● Medium priority area

● High priority area

Impact zones: high, medium, low.

5.9.5. Conclusion

Oil spill can seriously reduce the value of usage of coastal sites for recreation, will smother harbours and marinas and will possibly destroy coating of boat hulls. The impact on tourism as an industry may thus be considerable.

Our assessment shows that the high priority areas are mostly situated near high densities of population. The outer part of Andøya - Vesterålen, an area around Nesna municipality on the Helgeland coast, the Nærøy - Vikna coastline and in particular the outer and inner parts of Trondheimsfjorden are the most important areas for human usage.

This corresponds very well with the political aims of the counties. Important recreation areas are also given priority as tourist areas.

Especially the Trondheimsfjord is regarded as sensitive should oil contaminate the tourist and recreational sites. The probability that this may happen after an accident at the Heidrun field is present, but small. The whole inner part of the fjord and partly the outer is assumed in the worst case to be in the low impact zone for a spill from Heidrun. It is unlikely that significant quantities of oil would enter the inner part of the fjord. However, if oil should get into the fjord, it may cause considerable damage since the shores are mostly sheltered and consist of large stretches of depositional bottoms. These would act as sinks for accumulated oil and be a source for long term secondary contamination of nearby regions as well. In the outer part of the fjord, important sites in Bjugn, Ørlandet, Rissa, and Agdenes municipalities ought to be given attention for much the same reason.

With localization of the Heidrun operational base in Trondheim including a supply base in Hommelvik, the supply activity will be situated in a very important region for human usage. Hommelvik lies on the important coastline from Trondheim to Stjørdal. We assume that the base activites themselves (boat traffic) will only have limited impact on other usage in the area, and that the potential conflicts between the establishment of the base and other local or regional interests in the area must be attended to as all other building projects before the base can be established.

In the high impact zone two areas ought to be given special attention. These are the Vikna - Nærøy area in the south of the zone and the Helgeland coast around Nesna in the middle/north of the zone. The outer part of this coastline is without shelter to the sea. This imply great exposure to oil spill, but also great exposure to waves. Heavy waves will quickly erode oil deposits on bedrock, but may also transport the oil onto land above the shore, and thereby reduce the recreational value of the areas given priority. Other important sites for human usage are situated in the inner parts and more sheltered to waves.

The outer part of Andøya - Vesterålen is situated in the medium impact zone. The outer coastline is, as the Helgeland coast, strongly exposed to waves. The area has a great deal of sandy beaches which have high sensitivity to oil spill. Heavy waves may, as we have said, help cleaning up quickly, but may also transport oil onto land above shore, which would be a strong disadvantage for human usage.

6. SUMMARY OF FINDINGS

6. SUMMARY OF FINDINGS

6.1 Introduction

The present assessment aims at evaluating the environmental effects of the the development of the Heidrun oil field (Block 6507/7) at Haltenbanken. The report describes the ecological elements in the offshore and nearshore/inshore regions which may be impacted by the development, and appraise the possible effects on these both from routine operations at the Heidrun field (including heliport and supply base activities), and from possible accidents (single surface oil spills, pipeline rupture, and blowout).

NIVA has been responsible for performing the project and for producing the final report. Certain elements of the report have been compiled by other organisations: the Norwegian Polar Institute (marine mammals), the Norwegian Directorate for Nature Management (seabirds), and the Norwegian Meteorological Institute (oil spill drift modelling). These institutions have produced their own reports as basis for the relevant chapters of the main report.

6.2 Sources of effects

The discovery, development and production in an oilfield involves routines which potentially may affect the environment. Routine operations are well planned and involve a calculated possibility of minor environmental effects. Some incidents, however, are not planned and may result in extensive environmental impact, e.g. accidental oil spills. It is the nature of such incidents that irrespective of effort to avoid them, there always remains a certain possibility that they will occur.

The scenarios considered in this report are development according to current plans and regulations, sub-surface oilspill, and surface oilspill (blow out). Sources of effects are, physical presence of instalations, aerial and marine supply activity, offshore construction/commissioning phase, the development of supply and helicopter base, discharges from the platform, production water, drill cuttings and associated drilling mud and additives.

Experimental reearch and case studies are used in the evaluation of environmental consequences in this report.

The platform to be used at the Heidrunfield will either be a TLP (tension leg platform) or a condeep. A total of 53 wells will be drilled using a low toxicity oil based mud. The cuttings cleaning procedure adopted will be based on the type of platform used. The avarage density for the crude oil is 898 kg/m^3. The estimated production for the field is 200 000 barrels (US) per day. The locations for operation office, supply and helicopter bases are not yet decided. Four alternatives are suggested. These alternatives include at least one of the following cities: Trondheim, Kristiansund, Brønnøysund and Sandnessjøen.

6.3 Offshore environment

6.3.2 Primary productivity

Normal activity related to the development and production in the Heidrun field will not have any affect on primary productivity in the area. An major oilspill will cause concentrations of hydrocarbons in the euphotic zone toxic to phytoplankton and will cause reduced production. This loss is not substansial and probably not detectable under field conditions due to natural variability. Whether or not an oil spill will cause a change in species composition in the prevailing phytoplankton communities is not possible to predict. The direct repercussion of an isolated loss in primary production on higher throphic levels including fish, is not considered significant.

6.3.3 Fish stock and larvae

The Haltenbanken area contains spawning or nursery grounds for commercially important fish like cod, saithe, haddock, herring, plaice, redfish, ling, torsk and great argentin. Several of these species perform counter current spawning migration to the Haltenbanken area in order to compensate for drift of early life stages. Future distribution of fish stocks cannot be estimated accurately. The HELP research programme performed at the Institute of Marine Research in Bergen will, however, improve our knowledge on spatial and temporal distribution of early life stages of fish.

Normal activity on the Heidrun field according to current plans and regulations will have no significant effect on fish stocks. However, elevated concentrations of hydrocarbons may be found in fish attracted to the installations. Experience from oilspills indicate that after a major oil incident only very small amounts of petroleum hydrocarbons are found in fish tissues and only in a small portion of the fish examined. Tainting is a potential effect on fish offshore. The acquisition of taint may occur within 24 hours at concentrations comparable to those found under an oil slick. Tainting is a reversible effect which will be eliminated within 1 month after exposure has stopped partially through detoxification (MFO-system). Adult mortality from offshore activity is less likely than the effects on early life stages because adults may move out of suboptimal water masses.

Eggs and larva are more susceptible than adults. Documented effects are found at concentrations near 50 ppb, which are below concentrations found offshore after oilspills. Since the highest concentrations of oil after an oil spill are found near the surface, eggs and larvae in or near the surface (saithe, haddock, herring (larvae), and cod) are more susceptible than species with early lifestages in deeper water (red-fish, great-argentine, round head rat-tail). Benthic eggs (herring) are only affected in areas where drill cuttings are deposited. Important areas for herring are not found in the area potentially affected by cuttings (radius 5 km from source of discharge).

Effects on a yearclass or early lifestages would not affect fisheries before these individuals reach the age where they are harvested. The effect on future spawning potential of a loss in one yearclass will not be manifest until the yearclass reaches maturity. The effect of an oil spill on juvenile stages on future fisheries is therefore impossible to assess.

Larvae originating from the Trænabanken and Lofoten areas are not likely to be affected by the planned activity at the Heidrun field. However, larvae originating from areas to the south of and at Haltenbanken area may be affected if an oil spill occurs at the Heidrun field.

Long lineing is the most important fishing method used in the vicinity of the Heidrunfield. Loss of access due to the platform installations is insignificant compared to the total fishing ground. Normal development and production and probably also an oil spill are judged to have undetectable direct effects on fish stocks. The most vulnerable period is in late winter and spring, both for juvenile stages and for adults.

6.3.4. Physical and chemical characteristics of the sediment

The sedimentary environment of the Heidrunfield consists of sandy clay overlaying silty stiff clay with a mud content of more than 75%, which is very high compared to oil fields in the North Sea. The sediment is oxygenated down to 10 cm depth with slightly lower Eh values in the Heidrun field compared to other localities on Haltenbanken. The sediment is highly enriched in calcium carbonate due to the presence of shell fragments. The metal and hydrocarbon content indicates a pristine area.

The potential impact on the bottom sediments due to drilling and production are, (1) hypersedimetation of cuttings and drill mud in the near vicinity of the drilling location(s), area of influence will depend on discharge depth, (2) increased levels of metals (Ba, Fe, Cr, Ni, V), (3) increased levels of hydrocarbons in the sediment, (4) reduced availability of oxygen in the sediment.

The high mud content and the greater water depth of the Heidrunfield are characteristics which might modify the effects usually seen in the North Sea. High mud content indicates that the sediments are not particularly well oxygenated, thus the endemic benthic population can be expected to be somewhat tolerant to low oxygen levels.

6.3.5. Benthic and epibenthic macrofauna

Predictions of effects are based on previous results from monitoring of offshore operations considering the special conditions on the Heidrun field.

Four zones of effects are recognized around offshore production and drilling installations, (1) High impact zone with a highly modified community, 0-500 m, (2) Transition zone where community structure and diversity are slightly modified, 200-2000 m, (3) Physical/chemical affected zone with elevated levels of hydrocarbons or metals but with no apparent effects on the benthic community, 800-4000 m, (4) Unisturbed zone where no contamination or effects on benthos can be detected.

Experience from other fields indicate that discharge of drill cutting with associated drilling mud is the main cause of effect on the benthic communeties. Where low-toxicity mud systems are used, hydrocarbon concentrations in the range of 200-6000 mg/kg (ppm) in the sediment can be expected to show detrimental effects.

The benthic communities in the Heidrunfield in general conform to those reported for unpolluted sediments from the Norwegian Sea and the

North Sea.There was no evidence suggesting that benthic communeties were influenced by drilling operations performed before May 1985. However, the data base concerning epibenthic species is poor. The high mud content and the large depth may cause effects on the benthic community not predicted by experience from the North sea.

6.3.6 Seabird population

The oilspill modelling indicate that an oilspill from the Heidrunfield will remain in the sea for more than 5 days before it reaches the coast, and may thus potentially affect seabirds offshore. We are unable to predict the consequences or extent of damage to offshore birds caused by an oilspill due to lack of data. However,some potential affects are apparent.

An oil spill in the period March-May, could affect auks on their way to nesting colonies at Runde, Lovund and Røst. Young guillemots are, during their swimming migration in July-August, unable to fly and are extremly vulnerable to drifting oil et this track. We know that these birds migrate through the area potentially affected by an oil spill from the Heidrun field.

6.3.7 Marine mammals

The species of marine mammals found offshore in the Heidrun field area are basically all whales. The effects of oil pollution on marine mammals offshore is not extensively documented. For the baleen whales the ingestion of oil through feeding is one of the most relevant potential sources of effects, however, the effects of ingested oil in whales remain unknown.

The whales which are most likely to be affected from the activities at the Heidrun field, are: mink whale, fin whale, sei whale, killer whale, common porpoise and white beaked dolphin.

Several physiological, and pathological effects of oil on marine mammals are documented. Compared with the information available on the effect of oil on seals, little is known about the effects on whales. Actual observations in spill situations seem to indicate that whales either do not recognize floating oil or are not disturbed by it. There is evidence that behaviour of whales may be disturbed by offshore activity. The consequences of this is however not known. Blasts may most certainly cause death to whales in the surrounding area but will not threaten any populations.

Generally, the Heidrunfield development and operations may cause some disturbances which may effect whales, and in case of blasting perhaps death of some individuals. All over the effects on whales is considered to be insignifiicant.

6.5 Inshore and shore environment

6.5.1 Area of costal impact

The discharges from routine operations at Heidrun are not considered a threat to the coastal ecosystem. The establishment of supply base, whatever site option is chosen, is not assumed to cause significant impact on coastal ecology, except for the disturbance at the construction site during the establihsment. Boat and air traffic may under certain conditions cause short term behavioural disturbance of birds and mammals, but this is not considered to be serious with traffic frequency suggested. The most important impact of the Heidrun activity on the coastline is therefore considered to be from accidental oil spills drifting towards the coast.

Based on the postulated mean rates of oil input to the coast given by the oil spill drift forecast, the coast has been roughly divided into four zones:

high impact zone:	Vikna - Meløy
medium impact zones:	Frøya - Vikna, Meløy - Steigen, and Vestvågøy - Andenes
low impact zones:	Fræna - Frøya, Steigen - Vestvågøy, and Troms

The time oil will take to reach the coast will in general be more than 5 days, and most often between 10 and 20 days. It is therefore expected that the oil has lost most of the chemically toxic components to the water and air before the coast is reached.

A rough estimate of the expected amounts of oil which may reach the various zones of the coast under two relevant scenarios: a single spill of maximum 20 000 barrels/day over 10 days, and a major blowout of 100 000 barrels/day over 120 days, have been compared to the magnitude of recent spill accidents. This shows that the worst case of a single spill will cause shoreline pollution far less than most of the major tanker accidents, and in fact of the same magnitude as the "Dei Fovos" spill which hit the Helgeland coast in 1981. On the other hand a blowout of the magnitude suggested could in the worst case lead to a coastal pollution incident more severe than any hitherto recorded spill.

6.5.2 Types of shores and residence time of oil.

The bottom substrates in the tidal and subtidal areas have been divided into 3 major types:

Depositional substrata: mud, silt and clay

Transport substrata: coarse and fine sand

Erosion substrata: bedrock, boulders, stones and gravel.

The accumulation and residence time of oil on these substrates will vary with several factors. To generalize, the depositonal substrates will have self cleaning time in the range of 10-100 years, and may be a significant source of long term secondary contamination. Transport substrates are expected to be selfcleaned in 1-10 years provided the oil is not deeply buried. In the latter case the oil will be very persistent. Erosion substrates are assumed to be avoid of oil in 1-10 years in the case of loose material (boulders - gravel), and hours to months for bedrock shores. Subtidal depositional areas will receive less oil than in the tidal zone, but buried oil will also here remain almost undisturbed for years. Oil washed up above the tidal zone will be resistant to weathering. It may be gradually buried under plant debris and soil, which strongly reduces disintegration.

In the high impact zone from Vikna to Meløy we expect that large amounts of oil will be accumulated on shores with loose material in the outer part of the coast. A part of the oil may also be thrown on land especially between Vega and Lurøy where the sea is shallow and density of skerries is high. Oil which is transported into the fjords will quickly be eroded away from the sides of the fjord and end up on stony and sandy shores and in bays which usually have some areas of depositional shores. Large shores with depositional sediments are rare in the high impact zone.

In the northern medium impact zone the oil will have longest residence time if it beaches in the Lofoten - Andøya region. the Lofoten region is considered most vulnerable due to frequent occurrence of sandy and muddy shores fairly close to the open coast.

In the rest of the northern medium impact zone the outer coast is expected to have strong selfcleaning ability and stranded oil will probably be redistributed and accumulate in the fjords and landlocked bays.

In the southern medium impact zone the self cleaning ability of the outer coast is also considered large. Most of the shores are erosional, mainly bedrock. The coast along Frøya and the Froan archipelago have very complicated topography with dense occurrence of smaller bays, tide flats and skerries where oil may be thrown on land and be trapped for long time.

The longest lasting impact is expected if the oil enters the larger fjords of the southern region: the fjord system in Namsos municipality, and particularly Trondheimsfjorden. The dominating occurrence of transport and depositional sediments in the latter, makes it likely that oil entering the fjord will remain in the shore system for a very long time.

6.5.3 Fish spawning grounds

Systematic knowledge on nearshore spawning grounds does not excist, except for the major offshore fish stocks (cf. Chapter 6.3). In general stranded oil may smother nursery grounds and spawning areas in the intertidal and the shallow subtidal. Nearshore fish that may be affected are plaice and flounder, the juveniles of which remain in muddy and sandy tidal areas. Also several smaller species (gobids, pipefish, sticklebacks, etc.), which are importan prey to commercial fish like cod, stay in the tidal zone.

Spawning in coastal populations of cod and halibut occurs below the depth where the spawning might be threatened. Effect of an oil spill on the reproduction of fish which migrate into rivers for spawning (salmon and trout) is also considered to be small, but oil may disturb the olfactory orientation mechanism of the migrating fish. The edible crab spawns subtidally, and is not assumed to be significantly affected. In general animal reproduction occurs in late winter, spring and summer with the larval period in spring and summer, which is considered to be the most vulnerable period.

6.5.4 Inshore fisheries

Traditional inshore fisheries and harvesting of kelp and seaweed occurs along most of the coast, and have local significant economic value. The effect of oil on inshore fisheries is expected to be limited to temporary tainting of fish in enclosed bays and holding nets, and disturbance of fishing activity due to smothering of gear and holding nets. Kelp harvesting will be marginally affected, but harvest of tidal seaweed may suffer a long-term interruption if the weed is extensively smothered.

The main potential impact is considered to be on aquaculture. This industry is becoming increasingly more important. Today the industry has a commercial value of about 40 % of the traditional fisheries in Norway, and about 50% of the production in 1986 occurred in the impact zones.

The most common production method: dense rearing of fish in cages in the sea, is also the most vulnerable to oil pollution. Tainting may occur, which is temporary, but could reduce the marketing value for long time, smothering of cages and other gear possibly leading to reduced water exchange, and triggering of panic swimming in the fish which may cause severe lesions as well as oxygen deficiency. Mussel farming may also be impacted primarily due to temporary tainting. Land based rearing of smolt and older fish is not considered in jeopardy, since the water used is either fresh water or sea water taken at some depth.

Fish farming sites are scattered along the whole of the coast. At present the most important areas (based on density of sites) are the island region of Smøla, Hitra and Frøya, the coast from Bjugn to Vikna, from Tjøtta to Meløy and the inner part of Lofoten, but one must expect other areas to become just as important as the industry develops. The inner part of the fjords are sparsely utilized.

6.5.5 Sensitive shores.

The nearshore ecological communities have been categorised and ranked according to expected sensitivity and rate of recovery, on the basis of oil spill experience. Tidal mudflats and march areas are most sensitive, followed by tidal mixed and sandy shores. Supralittoral vegetation. shores with boulders and gravel, and subtidal soft bottom communities will be less severely impacted. Rocky shores may be impacted, especially if the oil strikes in late spring and summer when new organisms are settling, but recovery will be quickly initiated due to high selfcleaning ability, and strong settling potential by water borne recruits. Subtidal hard bottoms are not considered to be in significant jeopardy.

Sensitive communites are sparse in the high impact zone, but the coast from Alstadhaug to Dønna should be given slight priority as being most sensitive, because of the occurrence of tidal flats and valued supralittoral vegetation. In the northern medium impacted zone the Lofoten-Vesterålen-Andøya region is most vulnerable with vast stretches of sandy shores and mudflasts. In the southern medium zone oil will cause most shoreline damage south of Flatanger and in particular if it enters the Trondheimsfjord, where the largest soft sediment shores on the coast are found. On the other hand the probability that a major oil spill at Heidrun shall enter this fjord is small.

6.5.6 Sea birds

The potential impact zone is in general the most important section of the Norwegian coast for marine bird life. A significant proportion of the cormorant population breed in the area. Smaller colonies of shag breed at Froan, Leka and Vega. Eiders and greylag geese moult in the same area, and eiders breed along the whole of the coastline.

The largest breeding colonies of auks in the influence area are found at Lurøy (Lovunden) and Røst/Værøy. The third large site is Rundø, but this is considered to be south of the impact zone. Froan and Vega are two of the most important breeding areas for black guillemots in Norway and an oil spill here may have drastic consequences for the entire population of this species.

Birds which are particularly vulnerable to oil spills will differ with season. In summer large flocks of the various auk species gather on the sea outside the major colonies, mostly reproductive adults, and an oil spill in this situation will have long term consequences. Estimates suggest 50 years recovery time if half of the breeding population is lost. For guillemots a general decline in populations in northern Norway has given colonies at Runde and Røst/Værøy an increased importance.

Moulting seabirds congregate in dense flocks, and with reduced flying ability. The moulting season is in general from June to September. Damage to moulting duck populations (eider duck, greylag geese and velvet scoter) may be considerable in areas including Froan/Ørlandet and Vega.

Individual birds are especially vulnerable to oil during winter, both because they cannot sea the oil and avoid it and because the loss of plumage insulation is most severe at low temperature. The area of potential impact is the most important wintering area in Norway for most of the seabird species which are considered vulnerable to oil pollution. Cormorants inhabit most of the coast during the winter, with the highest concentrations at Froan. Oil hitting the coast of Froan, Vikna and Vega could also destroy large wintering populations of eiders, and similarly for velvet scoter in Frøya/Ørland, Vikna and Vega. Mergansers are also vulnerable to oil, but they occur in areas less likely to be exposed to oil. High mobility during winter further complicates the assessment of the potential impact on mergansers.

Normal helicopter and supply base activities seem to have no important effects on seabirds at any of the site options suggested for the Heidrun development. Helicopter flights at low altitudes should be avoided in the vicinity of cormorant colonies in the breeding season.

6.5.7 Coastal mammals

The coastal mammals considered are seals, otter, mink, deer, reindeer and domestic animals. Any oil spill will increase an already excisting oil fouling of the major common and grey seal populations from Nordmøre to Troms, in particular the colonies recorded at Froan, Vikna, Vega incl. Floholmane and Rødøy (Valvær). The consequence in terms of mortality is unknown, but individual suffering from lesions, problems in keeping heat balance, and subnormal population development may be potentially severe. An oil spill reaching grey and common seal colonies during the spring pupping season may severely reduce the populations.

Oil spills from the Heidrun field may deplete the populations of the European otter in the influence area and possibly endanger the future survival of the species in Norway.

The Heidrun activities will probably not have any significant effect on deer, reindeer and mammals used in husbandry.

6.5.8 Nature reserves and protected areas

On basis of the distribution and importance of the areas already protected or decided to be protected, and areas of scientific interest, the most important sections of the coast have been identified. These are the Trondheimsfjord, especially the middle and outer part which may receive oil; the Froan archipelago and coastline inside this from Bjugn to Agdenes; the Vikna-Leka region and Helgelandsøyene in Vega, all in the high impact zone; Karlsøyvær and Bliksvær outside Bodø; Røst; and the sand dune areas on the east coast of Andøya.

6.5.9 Human usage of the coast

The coastal areas valued for use in outdoor life and recreation may be damaged by oil smothering and rendered useless for considerable time. Our assessment shows, what might be expected, that the high priority areas of this kind are mostly situated near high densities of population. The outer part of Andøya - Vesterålen, an area around Nesna municipality on the Helgeland coast, the Nærøy - Vikna coastline and in particular the outer and inner parts of Trondheimsfjorden are the most important areas for human usage. This corresponds very well with the political aims of the counties. Important recreation areas are also given priority as tourist areas.

Especially the Trondheimsfjord is regarded as sensitive should oil hit the tourist and recreational sites. The probability that this may happen after an accident at the Heidrun field is present, but small. The whole inner part of the fjord and partly the outer is assumed in the worst case to be in the low impact zone for a spill from Heidrun, but should they be impacted, the shallow shores would act as sinks for accumulated oil and be a source for long term secondary contamination of nearby regions as well. In the outer part of the fjord, important sites in Bjugn, Ørlandet, Rissa, and Agdenes municipalities ought to be given attention for much the same reason.

In the high impact zone two areas ought to be given special attention. These are the Vikna - Nærøy area in the south of the zone and the Helgeland coast around Nesna in the middle/north of the zone. The outer part of this coastline is exposed, but some important sites for human usage are situated at locations more sheltered to waves, which would give prolonged residence time of any smothering.

The outer part of Andøya - Vesterålen is, as the Helgeland coast, strongly exposed to waves. The area has large stretches of sandy beaches where the wave action may erode stranded oil, but the waves may also transport oil onto land above the shore, reducing the recreational value for several years.

6.5.10 Conclusions

In summary we have tried to define the areas of the coast which on basis of all previous considerations are thought to be the most damaged by oil transported from the Heidrun field. They are indicated on Figure 6.1. As is expected a distribution compiled of a range of different aspects of vulnerability renders most of the potentially impacted coast vulnerable. Still it is possible to define certain high priority coastlines which are highly priored by several aspects considered. These are the Trondheimsfjord and areas around the entrance to the fjord, the coastline around Hitra, Frøya and Froan, the Vikna-Leka coast, the coast from Vega to Meløy, and the coast from Røst to Andøya. Comparing this distribution with the spill forecasting indicates that the valuable areas expected to be most damaged by an accident at the Heidrun oil field will be region from Vikna to Leka and the coast from Vega to Meløy.

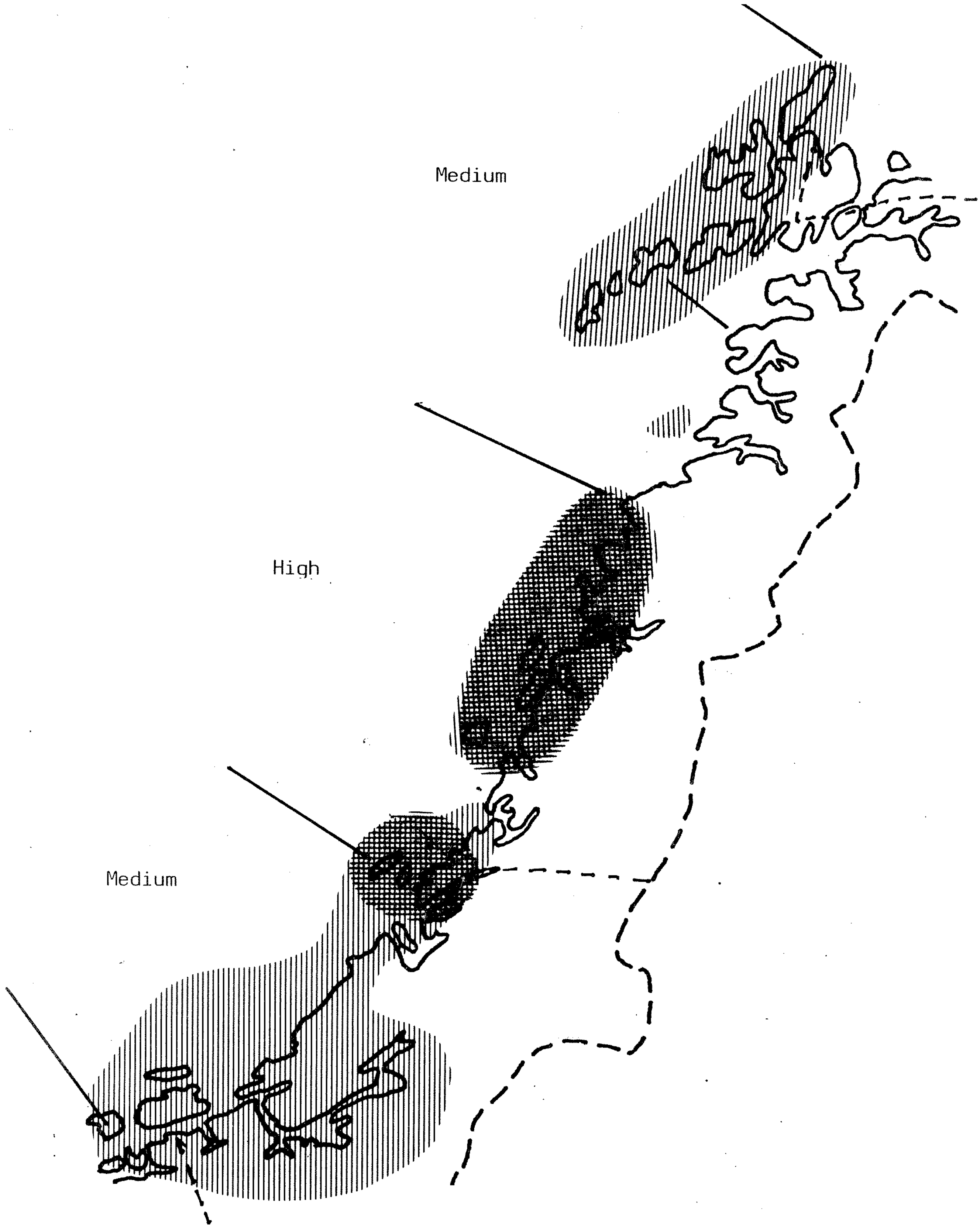
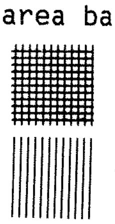


Figure 6.1 Indication of the most vulnerable coastline in the Heidrun impact area based on all sensitive elements evaluated.



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