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NORWEGIAN INSTITUTE FOR WATER RESEARCH
Blindern

0-25/77

BIOLOGICAL AND CHEMICAL INVESTIGATIONS AT
THE ISLAND SOTRA IN HORDALAND COUNTY, NORWAY

- programme of investigations -

Oslo, June 23rd 1977

Project coordinator: Cand real Tor Bokn
Co-workers: Cand real Ivar Haugen
Cand real Brage Rygg
Jens Skei, Ph D.


Director Kjell Baalsrud

PREFACE

Norwegian Institute for Water Research (NIVA) has prepared the present programme on the commission of Den norske stats oljeselskap (Statoil). The directives were stated at meetings at NIVA March 29th and June 15th 1977.

The main purpose of the programme is to outline the necessary biological and chemical baseline investigations at sites, expected to be influenced by oil activities, at the island of Sotra.

Oslo, June 23rd 1977



Tor Bokn

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1. INTRODUCTION

1.1 Presentation of the Institute

The Norwegian Institute for Water Research (Norsk institutt for vannforskning, NIVA) is a semi-governmental independent research institute.

NIVA was founded in 1958 by NTNF, The Royal Norwegian Council for Scientific and Industrial Research and operates as one of 15 such institutes.

According to the statutes the purpose of NIVA's activities are:

The institute's operations deal with all aspects of water quality.

Included are the water supplies for domestic, agricultural and industrial use, the transport, treatment and discharge of polluted water and the water quality of ground waters, rivers, lakes, estuaries, fjords and coastal waters in connection with discharge of pollutants or any other activity which affects water quality.

With this frame the institute's mandate is to:

1. Conduct research, development and investigations. Special attention shall be given to factors that appear important for a purposeful exploitation of Norway's water resources. Research activities should have a long-term perspective and be of interdisciplinary nature.
2. On a contract basis conduct research, investigations and advisory services for central and local governmental authorities, for industry and others.
3. Collect and distribute information to water users, planners, governmental authorities and others such that new results and developments both domestic and foreign can be useful applied in practice to insure management of water resources.
4. Contribute to its employees' development so that they can function within and outside of the institute to the best of their abilities.

The activities of the institute cover all types of fresh waters, estuaries, fjords and nearshore coastal waters. All aspects of water pollution are dealt with at NIVA as well as problems related to treatment, disposal and purification of waste water. In addition to its research activities the institute conducts repayment work sponsored by public agencies.

The institute cooperates closely with the Ministry of the Environment and other governmental bodies, as well as with domestic research institutions and universities.

NIVA cooperates with similar institutes in other countries, directly or through international organisations.

The total staff of NIVA is at present (May 1977) approx. 150, of which approx. 50 are research scientists.

The institute is governed by a board of five members appointed by the NTNF Council, representing municipalities, industry, universities, water authorities and health authorities.

Director of the institute from its foundation till today's date is chem.eng. KJELL BAALSRUD.

The institute includes sections for:

- Freshwater Investigations
- Fjord and Coastal Water Investigations
- Industrial Water Problems
- Water Technology Development
- Ecology
- Chemical and Biological Analysis
- Data Processing and System Analysis

NIVA has an experimental research station at Kjeller, approx. 25 kms N.E. of Oslo, for studies on sewage treatment. A small marine experimental station is some 30 kms south of Oslo. At Hamar, NIVA operates a laboratory and field station for investigations of the problems represented by pollution of lake Mjösa.

For studies of the effects of acid precipitation on forests and freshwater fish, the institute has field stations at several locations in southern Norway.

The operating costs of the Institute are covered in part (approx. 35%) by a general grant from the Ministry of the Environment and the remaining by repayment work on a non-profit basis.

NIVA issues a yearly report in Norwegian on the main research activities problems and experiences during the preceding year and also a monthly and modest news bulletin in Norwegian. Results of research projects and consultant jobs are presented in written reports. The library, regularly issues lists of publications.

1.2 Aims of the project

The main purposes of the project are as follows:

1. To establish a base-line with respect to water chemistry, sediment geochemistry and marine biological conditions within specified areas at the island Sotra.
2. To observe present day levels of hydrocarbons and other chemical constituents, together with descriptions of the structure of shore and shallow water communities. These informations will serve as reference data in relation to future monitoring of the area.

1.3 Further investigations

To ensure that the results of the biological monitoring are representative and to establish reliable baseline data, it is recommended that the investigations are carried out for one consecutive year. This is to neutralize the natural variations from year to year and to avoid the risk of meeting with exceptional conditions (see Syratt and Cowell 1975).

Investigations of the landing site alternatives will start later on, when the number of alternatives are reduced.

2. INVESTIGATION PROGRAMME

2.1 Preliminary work and planning

The institute has general experience of biological and chemical monitoring. To resolve specific problems related to oil transference and oil terminals, it should be valuable to consult international specialists.

Hence, the proposition is made to visit an well established oil-terminal like Milford Haven in South Wales and a terminal under construction in

Sullom Voe, Shetland, to have discussions with the researchers as well as the authorities. These visits will be supported by studies of relevant literature. The study-trip is suggested to September or October this year.

Monitoring of the communities of the rocky shores by the transect method has been carried out for several years in the vicinity of the Rafinor refinery at Mongstad by an English research group.

This year the observations were conducted between 29th April and 10th May. As part of the planning of the Sotra investigation we took the opportunity to contact the group and participated in its fieldwork on the way to Sotra to check on shoreline conditions.

Included in the preliminary work is a registration of already existing discharge of waste in the investigation area.

2.2 Water chemistry

The prime objective of the water chemistry programme is to establish background levels of hydrocarbons in the water, i.e. naturally occurring hydrocarbons (lipids) and the existing contamination level. In addition to quantification of total hydrocarbon content it is important to characterize the various components.

It is assumed that the impact of the oil activities on the waters surrounding Sotra will be mainly local. Particular attention is paid to the water quality in the immediate vicinity of the tanker-terminal at Vindenes. It should be pointed out that the Vindenes Poll is especially vulnerable due to a shallow threshold and restricted water circulation.

The area of investigation includes the terminal at Vindenes, situated at the northern part of Sotra (fig 1).

At the terminal site 10 water stations are desirable; 3 stations in the Vindenes poll, 2 at Misjeosen and 5 between Vindeneskvarven and Kalvaneset lighthouse, including a profile towards Hanøy, see fig 1.

Water is sampled in the upper few cms of the surface layer and near a possible density-boundary. The sampling must be repeated a minimum of four times during one year, to investigate the natural fluctuations of the content of hydrocarbons related to biological production, freshwater runoff etc.

The water samples will be analysed for hydrocarbons (including characterisation), total organic carbon and salinity, temperature and oxygen. Water samples in the Vindenes poll will also be analysed for nutrients.

2.3 Sediment chemistry

The sediments play an important role in the aquatic environment for two main reasons:

1. The sediment acts as a substrate for bottom living organisms.
2. The sediment may be a reservoir for pollutants.

Certain fractions of the hydrocarbons accumulate in the sediments, where a further degradation may take place. The composition of the sediments will indicate environmental changes during a certain period of time, which makes sediment studies suitable in monitoring work.

To register the overall effect by the civilizatoric impact on the waters surrounding Sotra it may be advisable to analyse the sediment samples for heavy metals as well as hydrocarbons. The metals concerned are particularly lead, copper, mercury, cadmium and nickel.

It is recommended that sediments are sampled at the same sites as the water is collected, using gravity corer.

At the terminal site five sediment stations are recommended. Two of these cores (one from the Vindenes Poll and one outside) are analysed from deeper sections of the core, allowing a complete characterization of the hydrocarbons present in the sediments. All the sediment samples will be analysed for total organic carbon and heavy metals.

The sampling will only be necessary at one occasion prior to the operation of the oil terminal at Sotra. The sampling should be repeated every fifth year.

2.4 Biological investigations

The aims of the biological monitoring are:

1. Prior to petroleum activities at Sotra.

To establish the structure of the biological communities, their composition and condition.

To describe the extent of ecological fluctuations due to natural factors.

To analyse various organisms for hydrocarbons and phenols.

All together these data will constitute a baseline for further monitoring.

2. After starting of the oil-terminal operations.

Detect possible ecological effects from oil-terminal activities.

If detrimental effects are observed, an assessment of the area influence should be made.

To state if the area of influence is increasing, decreasing or remaining static.

2.4.1 Monitoring of the biological communities of the rocky shore

The biology of the area is characterized by rocky shore communities with a marked littoral zonation of organism.

The extreme spring tidal range of approximately 1.8 m is critical in relation to the transportation and deposition of any oily wastes from effluents or from spillage during tanker loading operations. Some parts of the Sotra shoreline are exposed to quite heavy wave action at certain times of the year. For this reason the "splash zone" is frequently extended vertically several meter above extreme high water springs. Hence, it is necessary to extend the monitoring to top of this zone, which may be the upper limit of oil and effluent influences that could occur during heavy wave conditions.

Shore surveys (transects studies), recording the vertical distribution and abundance of about 40 common littoral species, will be carried out at 14 stations. The same stations will be visited once a year during the whole monitoring period. It is therefore important to select the stations in sites which are not destroyed or disturbed during the construction period.

Reference stations will be established in sheltered and wave exposed localities some distance away from Vindenes.

These reference stations are important for the assessment of any changes occurring as the result of extreme weather conditions (i.e. severe winters, hot summers, heavy storms or any other natural phenomena).

At each station a belt transect will be investigated from extreme low water spring to the top of the "splash-zone". The transect will be divided into strips separated vertically by approximately one tenth of the tidal range, modified after Moyse and Nelson-Smith (1963), Crapp (1971) and Syratt and Cowell (1975).

The best working period for this type of monitoring is the period having the longest consecutive run of low tides approaching chart datum and coinciding with the commencement of the active growing season (Syratt and Cowell 1975). This usually occurs in May in the Bergen district. It is therefore recommended that the baseline transect work is conducted this month.

The investigations in 1977 were carried out 30th May - 4th June.

To establish further reference data 20 samples of organisms at different biological stations will be analysed three times a year for petroleum hydrocarbons (total and characterized) and to some extent phenols.

2.4.2 Remote sensing of the benthic algal vegetation

Remote sensing will give information on occurrence and distribution of dominant species and communities of the benthic algal vegetation. This is to be used as background material in the event of future pollution of the waters surrounding the island which may cause a change in the biota.

Remote sensing gives the possibility of surveying large areas synoptically at relatively low costs. The use of infra-red false-colour film (IR-film) makes it possible, when combined with ground truths, to identify and classify dominant algal species. The film records are filed for future reference following a brief analysis to compare the signatures on the film with ground truths.

The area of study is approximately 19 km long and 4-5 km in width. Stereo records of this area will be made in 1:20 000 and 1:5 000 scale.

2.4.3 Examination of hard-bottom biological communities by stereo-photography

One purpose of this part of the work is to obtain data on the sublittoral communities of sessile organisms down to 30-35 m depth at several localities in order to assess the quality and vulnerability of the different areas from the biological point of view.

A second purpose is to establish reference data as a basis for documentation of possible future damage to the biological communities.

The stereo-photographic method is mainly used for obtaining records of fixed test areas. In this way well defined areas can be photographed at intervals without interfering with the organisms. The method is thus especially suitable for observing long term changes. A description of the method is given by Lundälv (1971), see Appendix.

The technique developed at NIVA is a modification of the Lundälv method, the main difference being a synchronized double camera instead of a single one. This allows use of the system independently of fixed positions, which is preferable in the initial survey of an area. In phase 1 the "free" survey technique will be used. In phase 2 permanently marked positions on hard bottoms will be photographed.

Phase 1: Hard bottoms down to 30-35 m depth should be examined at 4 stations in the area surrounding the location of the terminal at Vindenes.

Phase 2: This phase includes establishment of reference data on hard-bottom communities at 4 fixed stations.

Permanently marked strips of 0.5 x 3 m at 5, 10, 15, 20 and 30 m depth will be photographed three times preceding the start of the petroleum activities.

3. COOPERATION WITH OTHER LABORATORIES

Petroleum hydrocarbons analysis will be carried out at the Central Institute for Industrial Research (SI) in Oslo. The methods used are described below.

Petroleum hydrocarbons consist of several types of chemical substances that are often difficult to separate analytically. Presently, selected aliphatic and aromatic constituents are most frequently encountered in environmental studies, and, in the present proposal, these types of hydrocarbons have

been included. More precisely, the alkane pattern will be determined by high resolution gas liquid chromatography (GLC), and the content of aromatic hydrocarbons will be analysed by either GLC, coupled gas liquid chromatography-mass spectrometry (GLC-MS), high performance liquid chromatography (HPLC) or fluorescence spectrophotometry. Before the actual quantification by an appropriate instrumental method, one or more steps of isolation, purification or separation is usually necessary.

The samples are extracted and the content of hydrocarbons are determined according to methods mentioned above. Some samples are characterized for aliphatic as well as aromatic individual constituents (method 1), while the rest of the samples are analysed for the content of individual aliphatics by GLC and the sum of aromatics by either HPLC or fluorescence spectrophotometry (method 2).

Cost per analysis are for water, sediment and organism samples respectively: N. kr. 600,- (method 2), and N. kr. 1 000,- (method 1), 1 000,- and 1 500,- 2 000,- and 3 000,-. Total cost for all samples amounts to N. kr. 216 000,-, which is included in the budget (see chapter 6).

4. TIME-SCHEDULE

It is always difficult to give an exact time-schedule, due to the dependance on weather and hydrographical conditions during the field-work. With these reservations the following programme is proposed.

Water for chemical analysis is sampled in September/October, December/January, April, June 1977/78 and April 1979.

The sampling of sediments will be carried out during the water sampling cruise in April 1979.

Monitoring of the biological communities of the rocky shore have to be conducted in May 1977, May 1978 and May 1979, due to tide conditions. Sampling of various organisms for chemical analysis will be carried out in connection with the biological monitoring in May 1977 and 1978. In addition a third

series of samples will be collected during a stereophotography cruise in October/November 1977.

Remote sensing by aircraft will be carried out during the monitoring of the biological communities of the rocky shore in May 1979.

Examinations of the hard bottom biological communities by stereophotography are separated into two phases. Phase one, the introductory field observations, can be terminated by 15th September 1977. In phase two, three cruises are programmed. The first one will take place during November 1977, the second will end prior to June 1st 1978 and the third can be terminated by October/November 1978.

Brief reports will be forwarded to state the progress of the field programme.

A preliminary report including the investigation from May 1977 to June 1978 will be finished during September 1978. The final report is assumed to be terminated by December/January 1979/80.

The institute reserves the right to make small changes of a technical nature in the above programme without notice. Any deviations implying change of information gained or delays, must be subject to the approval of the sponsoring authorities (project sponsors).

5. LITERATURE

CRAPP, G. B., 1971: Monitoring the rocky shore in "*The Ecological effects of oil pollution on littoral communities*" (ed. E. B. Cowell). Institute of Petroleum, London pp. 102-113.

LUNDÄLV, T., 1971: Quantitative studies on rocky-bottom biocoenoses by underwater photogrammetry. A methodological study. *Thalassia Jugoslavica*, 7: 201-208.

MOYSE, J. and NELSON-SMITH, A., 1963: Zonation of animals and plants on rocky shores around Dale, Pembrokeshire. *Field Studies*, 1: 1-31.

SYRATT, W. J. and COWELL, E. B., 1975: The littoral ecology of the area around Mongstad Refinery, Fensfjorden. Report. Rafinor A/S and Co. Mongstad (mimeographed, 28pp. + tabl., figs. and appendixes).

6. BUDGET

This budget is calculated on the basis of 1977 prices and an expected increase of 15% in 1978 as well as in 1979. In case of extra work caused by bad weather, the cost must be paid by the project sponsor. The same applies to extra work imposed by the sponsoring authority, which may lead to a budget increase. This is a budget estimate, the actual cost will be based on spent time and direct expenses.

Preliminary work and planning

Introductory visits to Mongstad/Sotra		
1 person in 3 days	kr 5 300	
Travel, allowances	<u>" 1 700</u>	kr 7 000
Visits to United Kingdom		
2 persons in 5 days	kr 13 000	
Travel, allowances	<u>" 8 000</u>	" 21 000
Literature studies		" 25 000
Registration of existing discharges of waste at Sotra		" 15 000
Administration and meetings		" 25 000

Water and sediment chemistry

1977

Field work: 2 persons in 2 days á 2 times, included preparations	kr 17 000	
Travel, allowances	4 500	
Boat hire	3 000	
Water analysis	26 000	
Data processing	<u>15 000</u>	kr 65 500

1978

Field work: 2 persons in 2 days á 2 times, included preparations	kr 20 000	
Travel, allowances	5 000	
Boat hire	3 500	
Water analysis	30 000	
Data processing, preliminary report	<u>30 000</u>	kr 88 500

1979

Field work: 2 persons in 2 days á 1 time, included preparations	kr 12 000	
Travel, allowances	5 000	
Boat hire	2 500	
Water analysis	17 500	
Sediment analysis	28 000	
Data, processing, final report	<u>25 000</u>	kr 90 000

Monitoring of the biological communities on the
rocky shore

1977

Field work: 2 persons in 7 days, included preparations	kr 31 000	
Travel, allowances	7 000	
Boat hire	2 000	
Biological analysis	16 000	
Chemical analysis	85 000	
Data processing, brief report	<u>16 000</u>	157 000

1978

Field work: 2 persons in 7 days, included preparations	36 000	
Travel, allowances	8 000	
Boat hire	2 500	
Biological analysis	18 500	
Chemical analysis	45 000	
Data processing, preliminary report	<u>46 000</u>	156 000

1979

Field work: 2 persons in 7 days, included preparations	41 000	
Travel, allowances	9 000	
Boat hire	3 000	
Biological analysis	21 000	
Data processing, final report	<u>66 000</u>	140 000

Remote sensing of the benthic algal vegetation

Stereo records of the area of investigation	kr 45 000	
Preliminary short analysis of the films	<u>13 000</u>	kr 58 000

Examination of hard bottom communities
by stereophotography

1977

Field work: (September and October/November)		
2 persons in 16 days, included preparations	kr 58 000	
Travel, allowances	15 000	
Boat hire, diving	25 000	
Picture analysis	<u>12 000</u>	110 000

1978

Field work: (May and October)		
2 persons in 10 days, included preparations	kr 41 000	
Travel, allowances	13 000	
Boat hire, diving	12 000	
Picture analysis, report	<u>29 000</u>	95 000

1979

Picture analysis	kr 40 000	
Final report	<u>23 000</u>	63 000

TOTAL:

kr 1 116 000

separated into 3 years:

1977:	kr 385 500
1978:	" 374 500
1979:	" 356 000

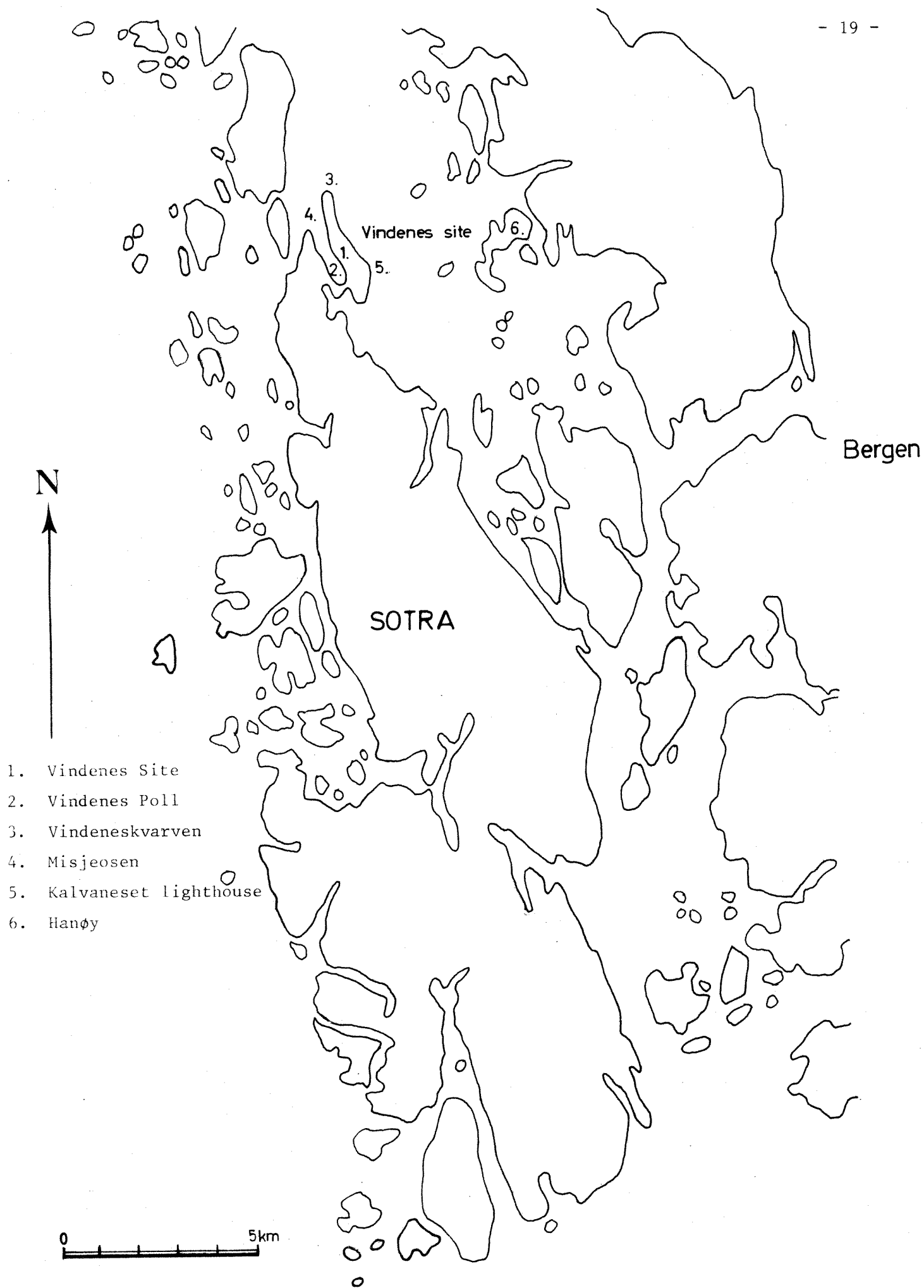


Fig. 1. Location of the investigation area