CRUISE REPORT

CRUISE 5, R/V "G.O. SARS", 3-18 April, 1996

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Summary

The main purpose of the cruise was to conduct studies on spatial distribution and dynamics of migrating herring schools in relation to gradients in environmental factors such as temperature, light and prey distribution. In addition the northern part of the EU zone was surveyed to reveal if Norwegian spring-spawning herring was present, and the Svinøy environmental transect was taken at the end of the cruise.

Migrating Norwegian spring-spawning herring were recorded in an area between 67° N and 68° N and 1° 20' W and 5° E. The herring occured in schools at 300-400 m depth in daytime, but rose to the surface and dispersed on some occasions at night. Forty-four schools were tracked for up to one hour, and the schools seemed to swim southwest at about 68° N and 0°, and southeast at about 67° N and 0°. The schools migrated at a speed of about 0.35 m/s, and appeared to be rather dynamic with frequent joining and splitting.

There were no herring in the northern EU-zone.

Scientific Personnel

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Introduction

The research programme *Mare Cognitum* was started at Institute of Marine Research in 1993 with the intention to study the physical and biological processes in the Norwegian Sea and their effects on commercially important fish stocks such as the Norwegian spring-spawning herring and blue whiting. As a part of this programme the research project "Herring in the Norwegian Sea" was started in 1995, and is supported by the Norwegian Research Council. This project is divided into several sub-projects, among them "Mesoscale school dynamics". The purpose of "Mesoscale school dynamics" is to quantify how environmental factors such as temperature, light, current, and prey distribution influence the behaviour of herring schools, and how the schools react to gradients in these environmental parameters. The quantitative results will be used as input to models for predicting the distribution of herring when feeding in the Norwegian Sea.

The main purpose of this cruise by R/V "G.O. Sars" was to conduct studies and collect data for the "Mesoscale school dynamics" project. The cruise contributed also to mapping the distribution of Norwegian spring-spawning herring at the onset of the feeding migration in the Norwegain Sea. In so doing the cruise is part of the survey activity in the Norwegian Sea that was coordinated and is subject to special reporting, data collection and distribution agreed upon by Faroes, Iceland, Norway and Russia in a meeting in Torshavn, 13-15 February 1996. In addition, a short survey in the northern part of the EU zone was conducted to accommodate a request from the Royal Norwegian Department of Fisheries. The cruise ended by environmental monitoring at the Svinøy transect as part of a century-long time series.

Since 1991 persons involved in "Mesoscale school dynamics" have had the pleasure of being in

contact with Professor T. J. Pitcher at the Fisheries Centre, University of British Columbia, Vancouver, Canada. Professor Pitcher has special expertise in shoaling behaviour of fish, and his knowledge is indispensable for putting the results from "Mesoscale school dynamics" in the right context. Accordingly Professor Pitcher and three of his students were invited to participate on the present cruise. Dr. C. Hollingworth, who has interest in fish shoaling behaviour and is an expert in copy editing of scientific journals, papers and books was also invited to participate in the cruise.

The challenge of herring migration: making optimal collective spatial decisions

Herring is a long-lived multiple spawner with strong variations in reproductive success between years. This species seems generally to adopt a low-risk, conservative strategy with shifts to e.g. an alternative overwintering area not taking place until there are large benefits. At the same time, herring is an extremely flexible species with great variations in migratory behaviour, both within and between populations.

Herring migrations have been investigated over many years. Most studies are, however, descriptive and little is published about the factors and mechanisms that govern spatial distribution. In this paper we try to interpret the existing observations from an ecological and evolutionary perspective, emphasizing proximate mechanisms that restrict the extent to which herring can attain an optimal distribution. The focus is on the Norwegian spring-spawning herring, but comparisons with other herring populations are also included.

Our starting point is that the migratory behaviour of herring can be explained by an interplay between relatively few driving forces. The environment in the Norwegian Sea shows strong spatial and temporal variations, with regard both to temperature and currents and to the abundance of food and predators, but there are some consistent features. With incomplete information about the environment and the key factors only to a certain extent predictable, herring could localize favourable habitats with a combination of predictive and reactive orientation mechanisms. Changes in the inner state, e.g. increased hunger level, could release westwards feeding migration in the spring by predictive mechanisms based upon genetic factors

and learning. This behaviour can be modified by reactive mechanisms, such as memory-based state-space comparisons and orientation to gradients in the sea (e.g. temperature). Herring may also keep within favourable areas by non-directional kineses influencing e.g. swimming speed.

Herring density varies in micro-, meso- and macroscale. After reviewing the available information on school density, school size, school size adjustments (splitting and joining), synchronized behaviour patterns and swimming speed of individual schools and school clusters, we attempt to connect the individual fish to large-scale distribution. The dynamics of large schools could result in the size and behaviour of the whole school not directly reflecting the optimal behaviour of individual fish, and the school should thus in many instances constitute the right level of analysis.

Survey area

From knowledge of the migration route of Norwegian spring-spawning herring from surveys by R/V "G.O. Sars" in 1993-1995, and of this year's distribution of herring in March obtained by the previous survey by R/V "G.O. Sars", the present investigaton was conducted in an area from about 67° N to 68° 30' N and about 5° E to 2° W (Fig. 1). The area was first investigated by an exploratory survey to map the distribution of herring. Tracking of schools for quantification of migration behaviour and school dynamics was then conducted along a southward transect along 0° starting at about 68°N, and along a westward transect along about 67°N starting at about 0° to 1° 20' W.

To accommodate a request from the Royal Norwegian Department of Fisheries, the northern part of the EU zone was surveyed by transects from 63° 30' N to 62°N along 1° 30' W, along 62° 15' N from 1° 30' W to 0°, and north along 0° from 62° 15' N to 63° 30' N. The final task of the cruise was to conduct standard environmental monitoring (temperature, salinity, water samples and plankton) at the Svinøy transect.

Methods

Continuous acoustic recordings of fish and plankton were made by a calibrated echo integration unit consisting of a 38 kHz Simrad EK500 working at a range of 0 - 500 m. The integration unit was connected to a Bergen Echo Integrator (BEI) for postprocessing of the recordings and allocation of area backscattering strengths (s_A) to species. A 95 kHz Simrad SA950 sonar was used to quantify the spatial distribution of schools in the study area in Smutthavet, and to track selected schools in the study area.

To record migration behaviour and school dynamics, selected schools were tracked for up to about one hour. The schools were then continuously recorded by the sonar system, and accurate position of the vessel was obtained from a Starfix differential global positioning system. The migration speed and direction of the schools was calculated by procedures written in SAS software. The dynamics of the schools were noted continuously by a rapporteur in cooperation with a sonar operator, both watching the sonar display.

Acoustic recordings of fish were identified by use of the Åkra-trawl, which has a vertical opening of about 30 m. By ordinary rigging the trawl can be used to catch deep recordings, but the trawl can also be rerigged to catch recordings near the surface.

Plankton was sampled in 4 to 8 discrete depths by a MOCNESS sampler in oblique tows starting from 200 m, 400 m or 700 m depth. Temperature, salinity, light absorption, and fluorescence were monitored by a CTD sonde up to 500 m depth. In addition, temperature, salinity, and fluorescence were monitored continuously from an inlet at 5 m depth in the hull of the vessel.

Biological sampling of herring catches

The biological sampling procedure was carried out as follows. One hundred herring were measured per sample; 50 of these were further examined for weight, fat content, sex, stage of maturity and stomach fullness. Thirty stomachs were frozen for further examination at the Institute of Marine Research in Bergen. Scales from 50 herring per sample were prepared for age-

and growth determination. Herring from 17 trawl stations were included in the biological sampling.

Temperature distribution

Temperature was recorded by CTD, ordinarily from the surface to 500 m at 5 m intervals. There were 28 stations (Figure 1, stations at Svinøy transect not included).

Contour maps were drawn for three depths: 5 m (representing the surface, where schools were often observed at night), 300 m and 400 m (many schools were encountered at such depths during daytime). Contours were placed by interpolation, and are subject to error.

The surface temperature declined from east to west (Figure 2). That at 300 m showed a 'tongue' of warmer, more dense water intruding below the cooler, less dense polar water extending from northeast to southwest (Figure 3). At 400 m, the tongue was again in evidence (Figure 4); the water was about 1°C colder than at 300 m.

In the region of this tongue, herring were swimming from northeast to southwest, then to southeast, and it would be tempting to speculate on the use of such oceanic features as migration corridors.

Herring distribution and migration

Herring was recorded across the continental slope from 66° N to 67°N, along 67°N to 1°20' W, along 68°N between 0° and 3°30' E, and between 68°N and 66°40' N and 0° and 1°20' W (Fig. 5). The herring was schooling at 300 - 400 m depth during daytime. At night the herring rose to the surface and occurred both in dense schools and in scattered shoals. Estimation of abundance can be made by regular conversion of s_A values by use of the night-time recordings only. During daytime the schools were swimming too deep for application of the commonly used target strength equation for conversion of s_A-values to fish density.

Forty-four herring schools were tracked for 5 - 90 minutes; 16 of these schools were tracked for more than one hour. The schools were mainly migrating at a speed of about 0.35 m/s. Even if most schools seemed to migrate in rather straight tracks, changes of heading occurred frequently. The absolute swimming speed seemed therefore to be about 1 m/s. At about 68° N and 0° the schools were heading south-west, while at about 67° N and 0° to 1° 20' W the schools were heading south-east.

There were no recordings of herring in the EU zone north of Shetland.

Biological status of herring

Four- and five-year-old herring of length about 24-31 cm dominated the trawl catches in the investigated area. The strong 1992 year class has left its nursery grounds and migrated into the Norwegian Sea. It represented 54% of the total catches, whereas the 1991 year class represented 32%. Herring of ages 6 and 7, with lengths 31-35 cm, accounted for 9% of the total catches (Table 1). The 1983 year class was present in only 3% of total catches, occurring in 8 trawl stations. In the sample PT 225, 16.7% of the herring were 13 years old, (Table 1).

The herring had some stomach content in most samples (Table 2). The stomach content varied, but increased substantially in sample PT 233, 66 57'N, 01 14'W.

Evaluating the dynamics of fish shoals: measuring herring in the Norwegian Sea.

Why are we measuring the dynamics of fish shoals? The answer is that we are doing it both for fun and for profit. Fun - because the knowledge is leading to greater understanding of a fundamental plasticity that evolution has built into the herring's life history and behaviour. Profit - because of the very practical applications of our new knowledge in devising management tools that encourage *sustainable* and *responsible* human exploitation of the herring resource. *Sustainable* means that harvest of a certain magnitude (as percentage of the total stock biomass)

may continue to be taken, and the term nowadays implies that, by quantifying uncertainty, you know, and find acceptable, the risks of taking such a catch. For shoaling fish this includes the risks of triggering a stock or range collapse and constitutes a rather different concept from the older idea of managing for the maximum sustainable harvest. *Responsible* means that the amount and means of harvest do not compromise genetic, biological or habitat diversity, for example by wiping out a less numerous sub-stock within a harvest quota, by damaging the sea bed with demersal trawling, or by catching unacceptably large numbers of other species as by-catch in a purse-seine or trawl.

From a long history of experiments and observations, we know quite a lot about how and why fish live in shoals, defined as social groups of fish. A shoal occurs because each individual fish makes second-to-second decisions to stay with its fellows. (When such co-ordinated swimming keeps them together, the group is termed a school.) Individuals may choose to leave (when foraging for example), and such choices may split or dissolve a shoal. Shoals stay together because individual fish maximise their fitness by making the choice to be social. Behaviour that enables the fish to make the choice has evolved: in some way the fish can evaluate the ratio of benefits and costs of being in the group compared with what would be expected if it were to leave this group and swim on its own. These *Join-Leave-Stay* decision rules (*JLS*) govern the formation and dissolution of fish shoals. Being a member of a shoal has a number of benefits in foraging and in reducing the effectiveness of attack by predators; being on your own reduces competition. Trade-offs between foraging for food and predation risk may be given different evaluations among individuals that vary in age, growth and reproductive potential. Not surprisingly, the motivational state of the fish influences shoaling decisions, for example hungry fish and spawning fish increase *Leave* decisions in relation to *Stay*.

Herring live in shoals for nearly all of their life. Hence they are regarded as having a strong shoaling tendency: an older classification as an 'obligate' shoaling fish conceals a great deal of plasticity that is reflected in the fluid form of herring shoals compared with, say, the phalanx-like schools characteristic of mackerel or tuna. Fluidity is brought about by changes in the balance among the JLS decisions, and can be seen on a short time scale as a herring shoal swims past and sub-groups move relative to each other, or on a longer time scale as the herring adopt different

shoaling patterns as they migrate between spawning, feeding and over-wintering habitats. Other species, such as saithe, are even more flexible, and some individuals may be found swimming in schools while other saithe forage as individuals. Herring are intermediate between these two types of shoaling fish.

The plasticity of its shoal dynamics endows herring with a remarkable ability to respond rapidly to each local regime of predators and food that it encounters on its life history migration. The herring maintains evolutionary fitness through growth, survival and spawning. Fitness is simply number of offspring of an individual that survive to reproduce. This provides a simple but powerful selective force that will produce the optimal JLS behaviour through the herring's feeding migration, spawning and juvenile life. It can also tune the JLS decisions according to a diurnal cycle, resulting in the herring's spectacular migration from 400m depth to the surface waters and back again every night. The herring is embedded ecologically and evolutionarily in its ecosystem by this behaviour.

Although the overall picture is clear, we know very little of the details of how these dynamics operate in the wild, as it has only recently been possible to measure herring schools using high resolution acoustics. If we understand the dynamics better, not only will we be better informed about the evolutionary mechanisms that shape the biotic systems in our oceans, but we could hope to better manage herring harvest, by for example, avoiding fishing places and times that are more critical for feeding or that make the fish more vulnerable.

On longer time scale, the sustainability of a fishery may be reduced by a collapse of range that happens along with stock collapse. (The opposite process, a range extension, occurs in times of increasing stock abundance.) Range collapse, combined with continued fishing by a fleet whose fishing power was generated by profits from the preceding era of high abundance, has led to economic disaster in a number of fisheries (e.g. Californian sardine, Brazilian sardine, Newfoundland cod). The combination of fishing and range collapse is depensatory (negatively density dependent) and difficult to recover from. According to one theory, range collapse may be engendered by shoaling itself (another theory blames environmental change) through meeting of shoals and joining. Measuring herring shoal sizes under different conditions of abundance

provides important evidence with which to evaluate the theory, and hence allows us to devise management that is precautionary against such risk of collapse.

How does what we are measuring on this cruise relate to these ideas and aims?

First, we are describing the short-term internal dynamics of herring shoals, something that has not been done before in the wild. Most previous work on herring schools may be likened to studying primate behaviour in zoos before quantitative field studies in their natural habitat began in the 1970s. In captive studies, some of the details may be right, and they are ideal for setting up carefully controlled experiments designed, for example, to sort out how fish perform trade-offs between feeding and predation risk. For fish shoals, the JLS decisions dynamics were elucidated from such experiments. But captive studies miss the integrated response to social milieu and environment that is the key to understanding evolution and ecology. There is an additional problem that some behaviour seen in captivity may be pathological. We have measured internal herring shoal dynamics in response to food (sampled at the same place and time) and in response to predators and in response to environmental factors such as temperature.

Secondly, we are attempting to relate these dynamics to the ocean regime of food and predators on several scales of space and time.

On a broad scale, we have gained some insight of how school dynamics are tied to local regimes of food and predation. On a previous "G.O. Sars" cruise in 1994, we recorded a range of fish predators such as cod and saithe accompanying small herring schools swimming at 30–50m depth. But the more offshore area surveyed here seems to be a regime dominated by behaviour that minimises the risk of predation by hunting marine mammals. Herring are found at 300–400m in the daytime in very large shoals. (There are some exceptions in our data set that may prove instructive.) At night they rise to the surface. We observed marine mammals in the vicinity (fin whales, killer whales, pygmy killer whales) and have sonar recordings that may depict attacks on herring shoals. Swimming deep during the day may represent an attempt to minimise predation by whales. Rising to the surface at night may be a response to vertical migration by food, but we have to await the results of the plankton and herring stomach sampling to verify

such inference. We hope to be able to show that an average herring during its 10-15 year life of annual migrations between ocean, spawning ground and over-wintering area, will be in a school that encounters predation by a marine mammal sufficiently often to shape its JLS behaviour.

On a finer scale of space and time, comparisons of measured attributes in this data set will allow us to tune models of shoal dynamics to Norwegian herring and perhaps construct a fine scale model of the movement dynamics of fish shoals. On a slightly broader scale, data on shoal splitting and merging will help our model of range collapse by providing details of the behavioural processes that accompany shoal encounters.

In conclusion, both fun, in terms of the insights of evolutionary ecology, and profit, in terms of strategies and tactics for better fishery management should emerge from knowledge gained on this "G.O. Sars" research cruise to evaluate herring schools in the Norwegian Sea.

Phyto- and zooplankton

In the end of March along the Svinøy transect, we observed a phytoplankton bloom at the shelf break and in the waters over the Norwegian continental shelf (see Report from "G.O. Sars" Cruise No. 1996004, 21.3.-01.04. 1996). In the beginning of April, along a transect from Halten to 67^0 N and 3^0 W (Fig. 6) we did not have detectable levels of fluorescence in our continuous measurements at 5 m depth in the shelf and shelf break region. This may have been due to mixing of the surface waters by a storm that passed through the area during the two days before we started the transect. However, there may also be a later initiation of the phytoplankton spring bloom in the Halten area compared with Møre. A deeper shelf in the Halten area may be the reason for this.

In the frontal zone in the western part of the transect (Fig. 6), algae on the MOCNESS nets and weak fluorescence measured by the fluorometer on the CTD sonde indicated an early bloom. On either side of the front, in the colder and fresher water to the west and the warmer and more saline Atlantic water to the east, the initiation of the phytoplankton spring bloom seemed to be delayed.

Detailed descriptions of zooplankton biomass distributions must wait until the samples are weighed. However, a qualitative inspection of the biomass samples under the microscope at sea gave us a preliminary impression of the vertical distribution of species and life stage distributions within species.

Calanus finmarchicus, the most important zooplankton species with respect to abundance in the sea and occurrence in herring stomachs, was found in a typical late winter-early spring vertical distribution. Maximum biomass was generally found below 200-400 m in all water masses. Another maximum was found in the upper 25 m of the water column. Our preliminary results seem to indicate that the fraction of the population found in the upper 25 m was greatest at the frontal stations. The specimens in the upper 25 m were mainly adult females, and at stations with an early bloom they were feeding and about to spawn. The occurrence of nauplii at some stations in the front showed that spawning had taken place. The population in the maximum below 200-400 m consisted of younger stages, the adults were of both sexes, and the females usually showed immature gonads.

Both MOCNESS samples and acoustics indicated a higher biomass in the upper 50 m in the northern part of the frontal area (68-68° 30′ N). MOCNESS and pelagic trawl samples showed that the biomass was mainly made up of krill and *C. finmarchicus*. This was the region with lowest herring abundances.

Thysanoessa longicaudata was the most common krill species in our MOCNESS samples. In Atlantic water with a deep scattering layer, *Meganyctiphanes norvegica* dominated the krill biomass. In the 2000 μm biomass fraction *C. hyperboreus*, arrow worms and amphipods dominated at the cold water stations. In warmer water, arrow worms, *Euchaeta norvegica* and *Aglantha* sp. were the dominating species.

Herring and their zooplankton prey - the sampling challenge

The distribution and school dynamics of Norwegian spring-spawning herring (*Clupea harengus* L.) have been studied by a SIMRAD EK500 echosounder with a 38 kHz split-beam transducer

and a SIMRAD SA 950 sonar, respectively. A multiple plankton net sampling system MOCNESS has been used to map the vertical distribution of meso- and macro-zooplankton prey.

The zooplankton samples are slightly separated in time and space from their associated herring trawl samples. They do, however, give a valid description of biomass, species composition and vertical distribution of prey organisms which it will be possible to relate to stomach content of the sampled herring. This information is appropriate to reveal at what time of the day feeding takes place, at which depth and what kinds of organisms are preferred. However, the relationship between schooling behaviour and foraging is difficult, if not impossible, to reveal and assess with the above-mentioned techniques. To study such processes in more detail, a new approach to zooplankton sampling with respect to school behaviour is needed.

The prime concern of studying foraging herring and their prey should be to measure the important parameters of herring school and zooplankton dynamics with the same spatial and temporal resolution.

The dynamics of a herring school - its change in shape, its vertical and horizontal speed, the joint-stay-leave decisions of single fish or groups of fish - implies that zooplankton surrounding the school must be frequently sampled with respect to time and space. To achieve this, a sampling platform carrying a diverse set of instrumentation for measuring zooplankton abundance and spatial structure is needed. The sampling platform must be flexible enough to operate from the surface to 400 m depth due to the day-night shift in herring vertical distribution. Due to frequent shifts in swimming speed and direction of herring schools, high manoeuvrability of the sampling gear is also of prime importance.

Blue whiting

One-year-old, 16 - 22 cm blue whiting were present up to 67°30' N and 1°30' W, but the densest concentrations were encountered at 300 - 400 m depth in the northern part of the EU zone, and off the continental shelf off Møre (Fig. 7).

Whale observations

We found it useful to include whale observations during the herring cruise. Marine mammals are presumably key predators on herring, particularly during the summer feeding period in the Norwegian Sea. Improved knowledge of distribution and behaviour of whales in relation to the Norwegian spring spawning herring may increase our understanding of schooling dynamics.

All whale observations were done visually from the bridge. The total period of observation every day varied substantially during the cruise. We have no accurate record of how long we looked for whales and how many persons participated from day to day. During the first part of the cruise (4-12 April 1996) it was nearly impossible to spot any whales because of strong winds up to 45 knots and many white caps at the surface. When we entered the polar front area at about 68°00' N, 2°00' W the fog was predominant and prevented whale observations. From 12 April we had calm seas and very good visibility (> 3000 m). Since this was quite early in the season we were not able to observe any whales in darkness from approximately 23.00 until 6.00.

We observed 12-17 fin whales, 12 killer whales, 2 false killer whales and 6 white sided dolphins (Table 3). Observations on the majority of fin whales were long (20 - 50 minutes) and detailed. We recorded the range, bearing and heading, group size and structure, diving pattern (how long they swam at the surface and underwater) and breathing frequency (number of blows and accurate time lag between them). In addition we recorded some fin whales on the sonar within 300 m of the vessel during daytime tracking (13 April). During two night sonar tracking periods (13-14 April) of herring schools, observation of unique dense echo patterns were seen, possibly whales because of the size and pattern of the echoes; visual confirmation was not possible because it was too dark. On previous cruises (June - August 1995 in the Norwegian Sea) similar echo patterns were observed and confirmed for many whales (killer whales, sperm whales, pilot whales and white sided dolphins) (see Cruise report R/V "Johan Hjort" 7 July-2 August 1995 on whale observations by Axelsen and Nøttestad). We passed the killer whales, false killer whales and the white sided dolphins during transects.

Dense and patchy distribution of plankton within 100 m of the surface were recorded on the

echosounder in close relation to three fin whale observations. Additionally, large and dense herring schools were recorded on both the sonar and echosounder in the same area as were 4-7 fin whales. Group size varied from one to five individuals, and the group structure consisted of narrow spacing (20-100 m) between group members. We may have recorded one group twice, as the vessel turned from a westerly direction to an easterly direction in a few nautical miles after we had last seen one group of fin whales slightly moving eastward. A more detailed summary from the behavioural observations of the fin whales will soon be available.

The data are not sufficient to state anything about the number of whales in the covered area. However, these observations represent useful pieces of information about behavioural aspects of marine mammals, and relation between whales and distribution of zooplankton and pelagic fish concentrations.

Table 1 . Length/age distribution of Norwegian spring spawning herring.
Length is total length, measured to nearest 0.5 cm.
Age class was determined by scale reading.

Length (cm)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Sum	Ubs a*	Total	%
21.0				1													1		1	.1
21.5																	0		0	.0
22.0					1												1		1	.1
22.5				1	1												2	1	3	.4
23.0			1		3												4		4	.5
23.5				1	3												4	2	6	.8
24.0				2	18												20		20	2.5
24.5				1	23												24		24	3.0
25.0					41												41	3	44	5.5
25.5					42	3											45		45	5.6
26.0					63	7											70	1	71	8.9
26.5					45	9	1										55	1	56	7.0
27.0					67	14											81	1	82	10.3
27.5					40	19											59	1	60	7.5
28.0					37	28	1										66	1	67	8.4
28.5					17	26	1										44		44	5.5
29.0					14	27											41		41	5.1
29.5					5	23											28	1	29	3.6
30.0					5	30											35	1	36	4.5
30.5						22	2										24		24	3.0
31.0						18	5							1			24	1	25	3.1
31.5					1	9	4	1									15		15	1.9
32.0						5	12	1									18		18	2.3
32.5						2	7	1									10		10	1.3
33.0						3	7	2									12		12	1.5
33.5						1	6	2									9		9	1.1
34.0						2	2	6	1								11		11	1.4
34.5								7	1					1			9		9	1.1
35.0								3	2					1			6		6	.8
35.5																	0		0	.0
36.0								1				1		1			3		3	.4
36.5								1	1			1		3			6		6	.8
37.0														5			5		5	.6
37.5														3			3		3	.4
38.0														5			5	1	6	.8
38.5														2			2		2	.3
39.0																	0		0	.0
39.5														1			1		1	.1
Sum	0	0	1	6	426	248	48	25	5	0	0	2	0	23	0	0	784	15	799	100.2
%	.0	.0	.1	.8	54.3	31.6	6.1	3.2	.6	.0	.0	.3	.0	2.9	.0	.0	99.9			
L**b	.0	.0	23.3	23.5	26.7	29.4	32.3	34.3	35.3	.0	.0	36.5	.0	37.2	.0	.0	28.5	27.5	28.5	
S(L)***c	.0	.0	.0	1.3	1.4	1.7	1.5	1.1	.9	.0	.0	.4	.0	1.7	.0	.0	3.0	3.9	3.0	

*a   Fish that could not be assigned to an age class
**b   Mean length (cm)
***c Standard error

Table 2. Stomach fullness by age of herring.

Fullness (a)	\							Age class (years)										Sum	Ubs(b)	Total	%
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+				
1			1		16	24	8	1	2					5			57		57	7.1
2				3	195	143	25	17	2			2		13			400	11	411	51.4
3				2	156	59	6	2	1					2			228	4	232	29.0
4				1	58	21	8	5						2			95		95	11.9
5					1	1	1							1			4		4	.5
6																	0		0	.0
Sum	0	0	1	6	426	248	48	25	5	0	0	2	0	23	0	0	784	15	799	99.9
%	.0	.0	.1	.8	54.3	31.6	6.1	3.2	.6	.0	.0	.3	.0	2.9	.0	.0	99.9			
M (c)	.0	.0	1.0	2.7	2.6	2.3	2.4	2.4	1.8	.0	.0	2.0	.0	2.2	.0	.0	2.5	2.3	2.5	
S(M) (d)	.0	.0	.0	.6	.8	.8	1.0	.9	.8	.0	.0	.0	.0	1.0	.0	.0	.8	.5	.8	

(a) 1 - Empty stomach
    2 - Very little content
    3 - Some content
    4 - Full stomach
    5 - Extremely full stomach
    6 - Forced expulsion of stomach

(b) Fish that could not be assigned to an age class.

(c) Mean fullness grade.

(d) Standard   error of fullness grade.

Table 3. Date, position, species and number of whales.

Date	Position	Species	Number
6 April	66°20.0' N 06°07.0' E	Killer whale	2
10 April	67°54.0' N 00°05.5' E	Killer whale	4
11 April	68°03.0' N 00°09.0'W	False killer whale	2
13 April	67°57.0' N 01°14.0'W	White sided dolphin	6
13 April	67°01.1' N 01°59.9'W	Fin whale	3
13 April	67°55.8' N 01°14.2'W	Fin whale	5
13 April	67°01.9' N 01°45.9'W	Fin whale	1
13 April	66°59.3' N 01°79.1'W	Fin whale	5
13 April	66°57.7' N 01°13.4'W	Fin whale	3
14 April	66°59.1' N 00°38.0'W	Killer whale	4
14 April	66°23.0' N 00°45.0'W	Killer whale	1
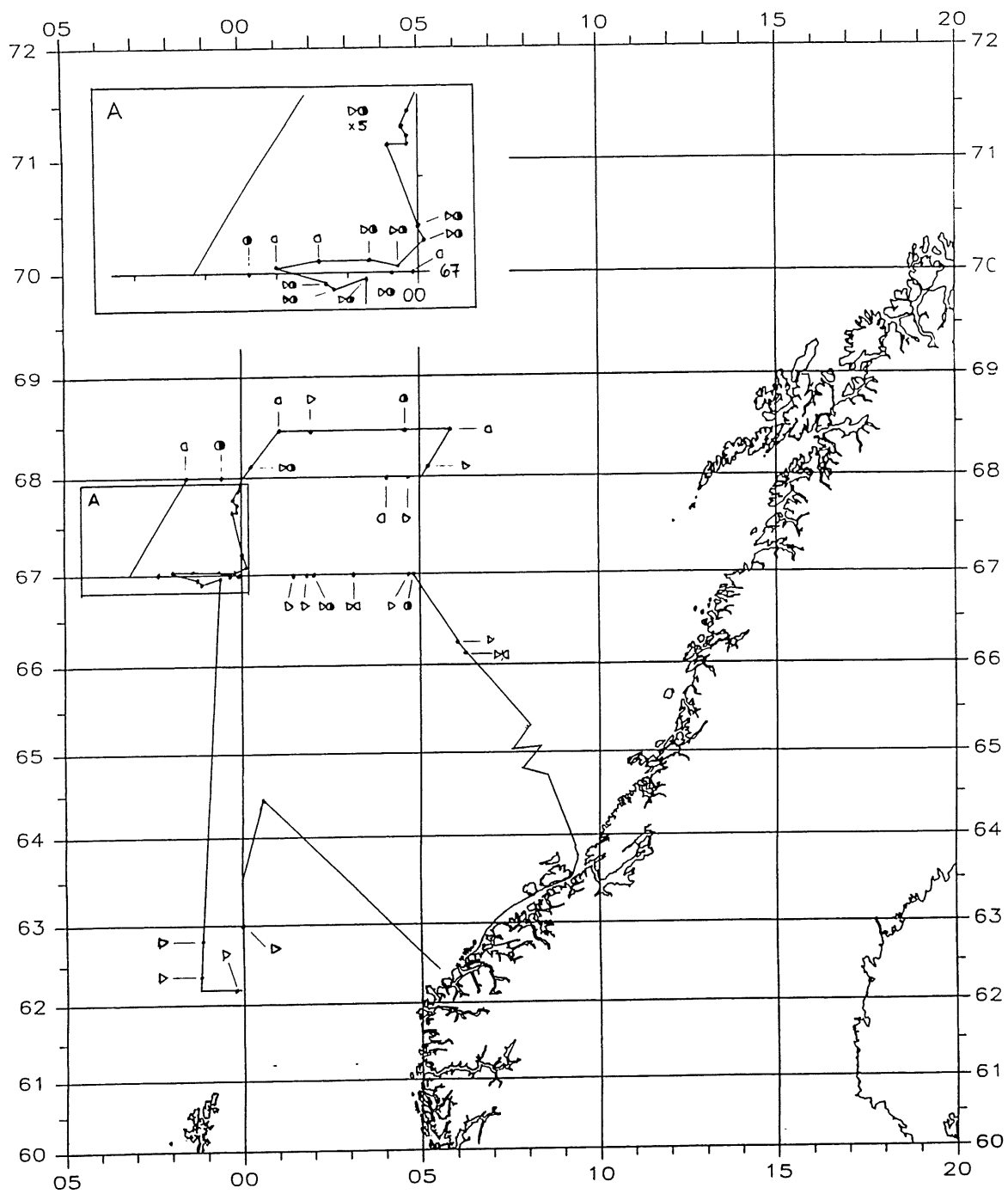
Figure 1. Cruise track. Dots show location of sampling stations, coded as follows: triangle, pelagic trawl only; half circle, CTD only; half-black circle, CTD and MOCNESS; triangle and half circle, pelagic trawl and CTD; triangle and half-black circle, pelagic trawl and CTD and MOCNESS.
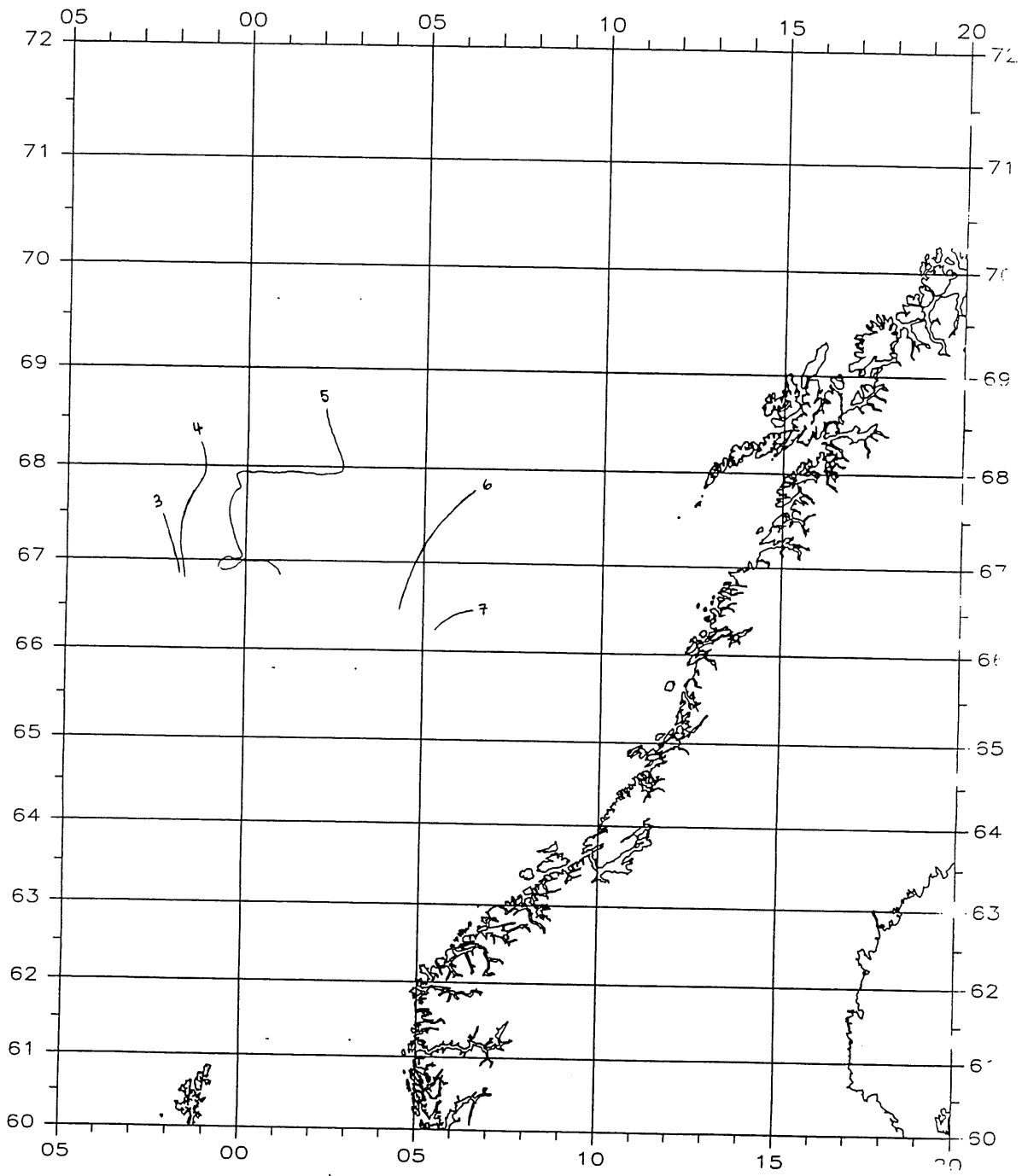
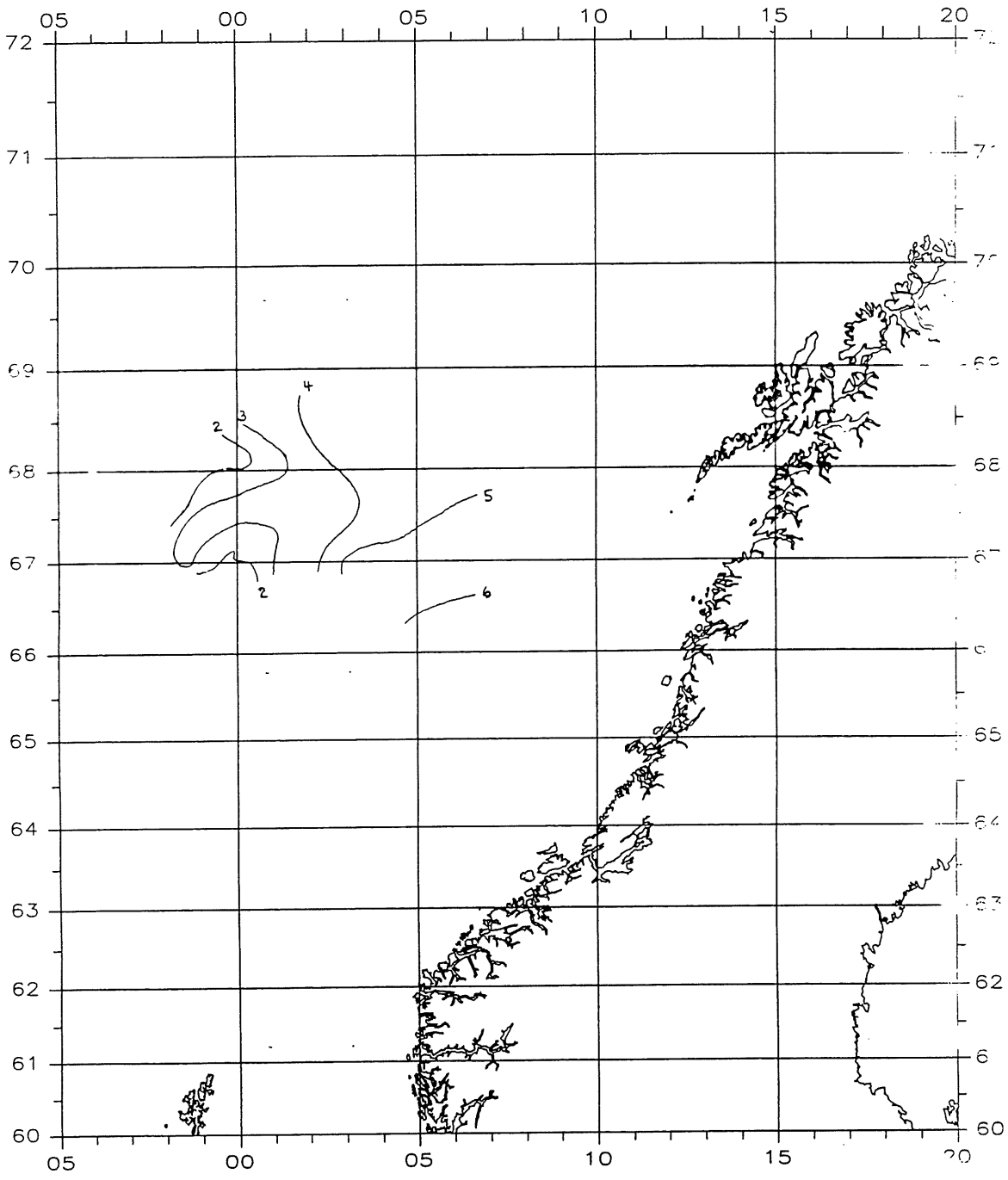Figure 2. Temperature distribution at surface (5 m).

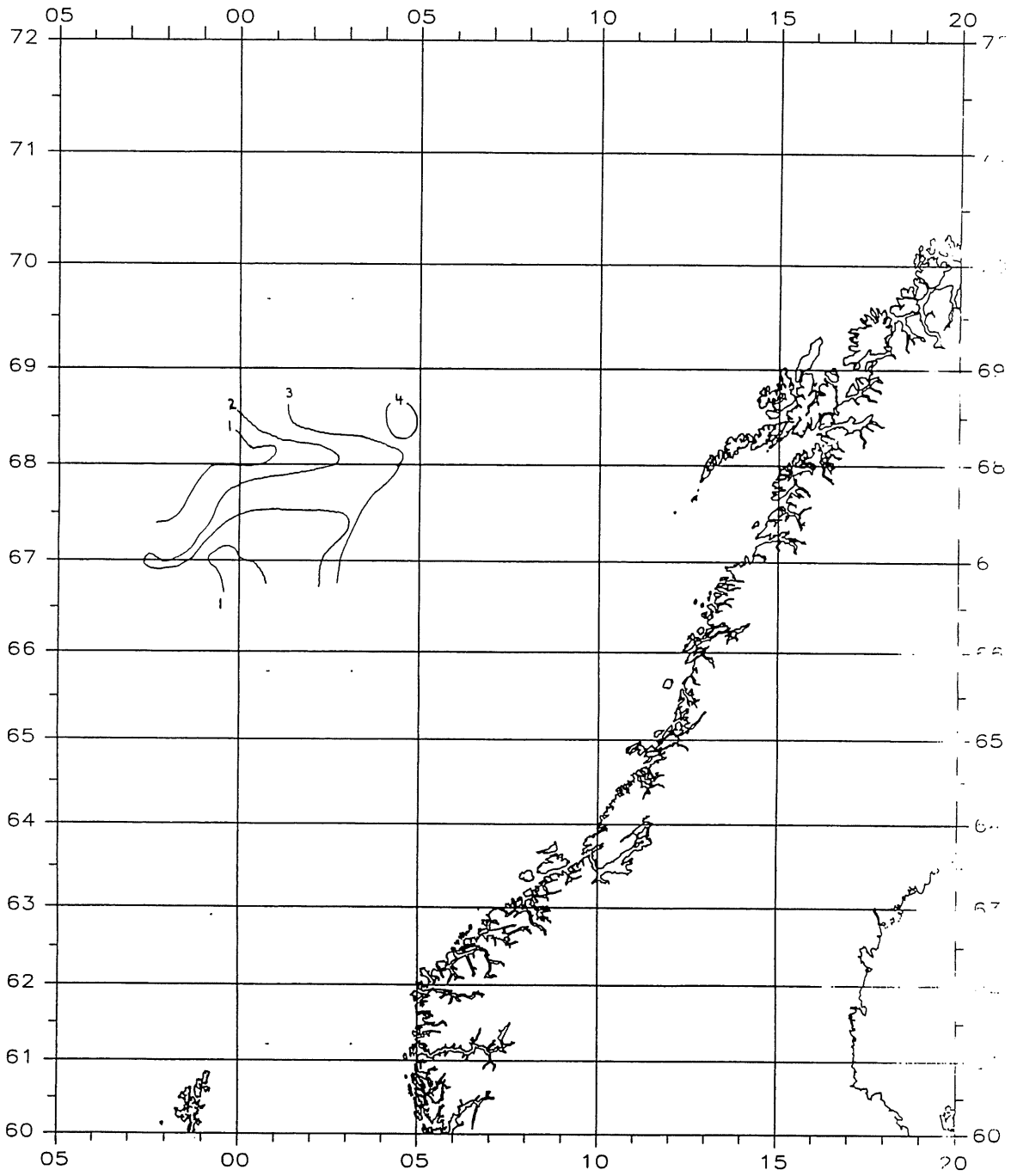Figure 3. Temperature distribution at 300 m depth.

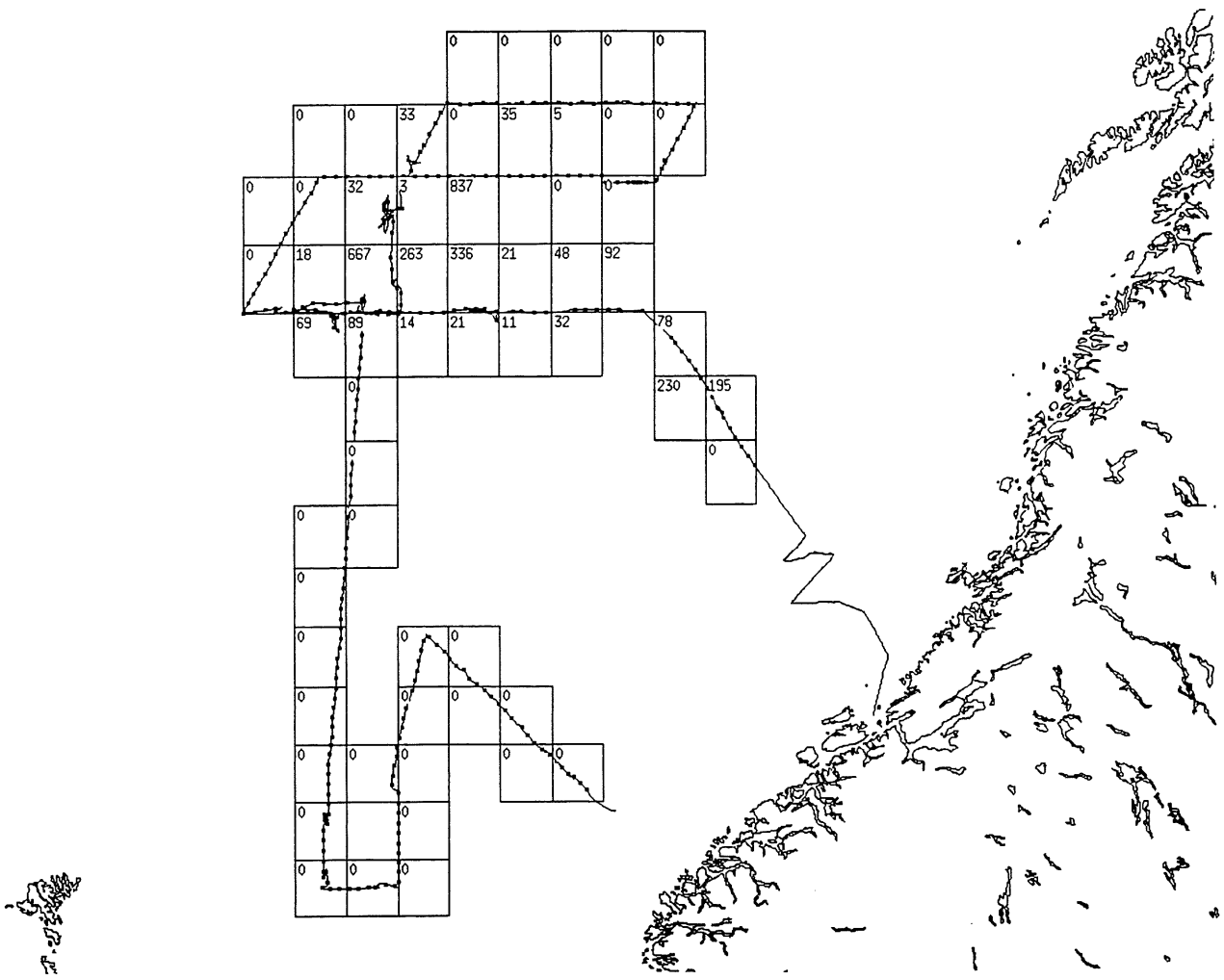Figure 4. Temperature distribution at 400 m depth.

Figure 5. Horizontal distribution of s_A-values allocated to herring as drawn by the BEI-map procedure in squares of 30' latitude and 1° longitude..
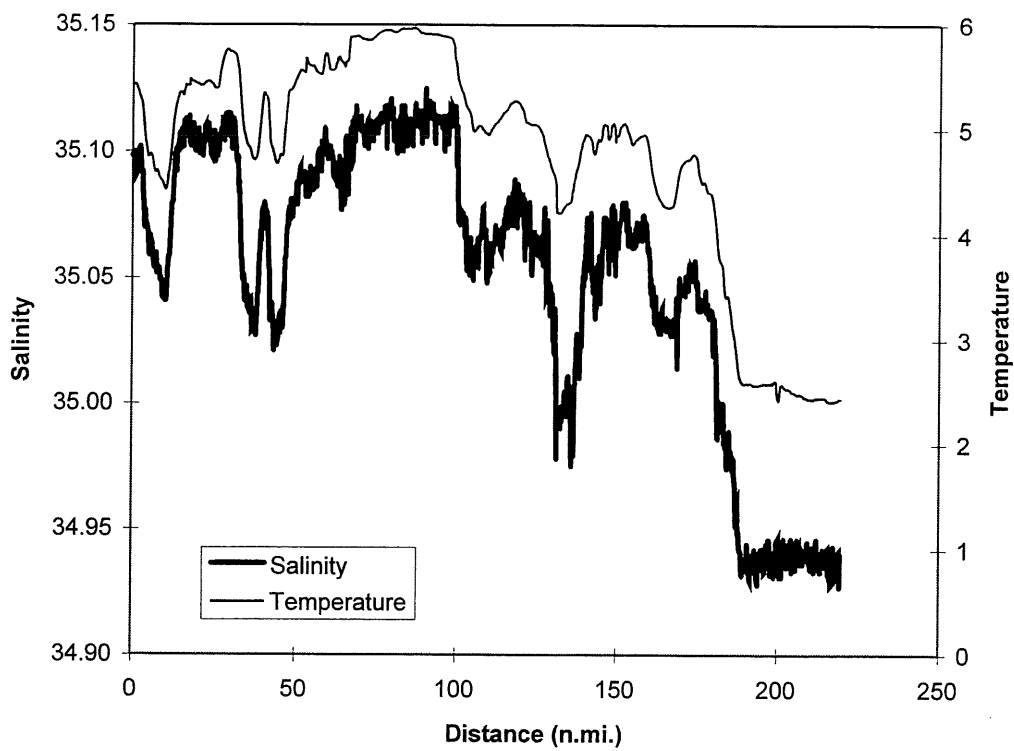
Figure 6. Temperature (°C) and salinity (‰) measured at each 0.1 nautical mile at 5 m depth along a transect starting at 67^0 $00'$ N, 04^0 $00'$ E (distance 0 n.mi.) and ending at 67^0 $00'$ N, 03^0 $00'$ W (distance about 225 n.mi.).
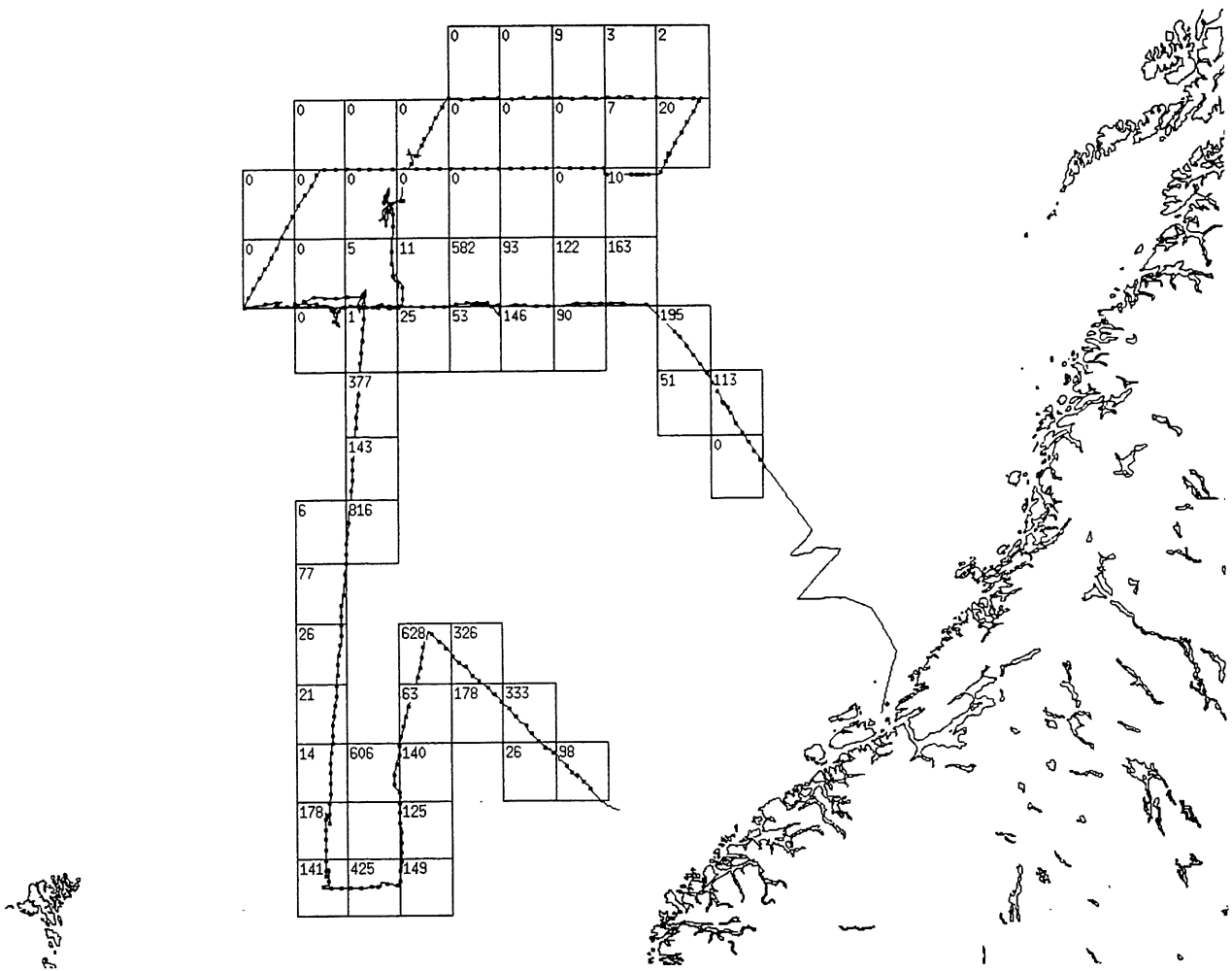
Figure 7. Horizontal distribution of s_A-values allocated to blue whiting as drawn by the BEI-map procedure in squares of 30' latitude and 1° longitude..

Appendix

Design of marine reserve for the Norwegian spring-spawning herring

Sylvie Guénette, Fisheries Centre, University of British Columbia, Vancouver, Canada

Nowadays, marine reserves are considered as a possible management tool to protect stocks from overexploitation. Marine reserves are believed to reduce mortality by controlling the fishing pressure and therefore allow mean age and size to increase. Since older spawners produce bigger eggs more likely to have better survival, recruitment would increase too. Reserves could also sustain a fishery by fish migration into the exploitable area. However, a reserve does not decrease the need for other regulations to limit the exploitation.

The Norwegian spring-spawning herring is partially protected from exploitation on its spawning grounds and the nursery area. The newly recruited herring is exploited by a tightly controlled Norwegian fleet operating in the fjords. At spring time adults move from the spawning grounds, heading west along the 67-68 parallel up to the polar front. By then the herring is well outside Norwegian waters and is vulnerable to an uncontrolled fishery. Although relatively stable, the migration patterns may shift abruptly to the north. An eventual reserve designed to protect the spawning stock should be large enough to include this migration route and its more common variations. Because strong emigration from the reserve decreases its efficiency by exposing fish to exploitation, international waters should be included in the reserve.

As the stock increases and its area of distribution expands, the herring is likely to spill over the edges of the reserve. If the actual stock was considered as the minimum acceptable size, then perhaps the proposed design would protect the minimal range of distribution. However, if the protected area is seen as an experimental device, then it should be possible to adjust its size and location as the stock size increases and the distribution area increases or moves.

At the moment, the herring overwinters in fjords along the Norwegian coast and its exploitation is relatively well protected. As the population grows back to its 1950s size, herring may resume

overwintering in Icelandic waters. Data about the proportion of herring migrating into Icelandic waters would be valuable for assessing the importance of this area compared with Norwegian waters. In this case, the setting of protected areas could be a joint venture between the two countries since it is in their best interest to keep a healthy stock. Protection could be granted to the stock in overwintering areas where herring is quite vulnerable and a restricted fishing zone could be established as convenient to both countries. A protected zone has the advantage of presetting the quantity of fish that can be caught notwithstanding the fishing pressure generated by the fleet. For that management tool to be effective, thorough monitoring of the spatial distribution of herring is needed to make sure that the reserve includes a substantial portion of the population. Acoustic surveys covering the total possible distribution area could be an effective method to assess the spatial distribution of the stock. The area where herring is more likely to be found would be covered more intensively than the remaining area which need only be checked.

Results from this cruise show how patchy and unpredictable is much the spatial distribution of schools. Moreover, it is evident that we don't know much about the motivation behind fine-scale migration. Therefore, to allow for adaptation to the year-to-year variations, an eventual protected area should not be established within a rigid frame. Monitoring of the spatial distribution is also part of the learning process and would aim to prevent coarse misspecification of the reserve.

Spatial Distribution of Herring Stocks and its Implication for Regulation of Fisheries.

Steven Mackinson, Fisheries Centre, University of British Columbia, Vancouver, Canada.

Fisheries on schooling pelagic fish are characterized by high variability. Herring fisheries in both the Atlantic and Pacific are perfect examples. During the periods of high abundance it was considered that such a resource could never be fished down: how wrong! Huge increases in effort resulted in high catch rates. Throughout the depletion of stocks, increasing catchability ensured that these high catch rates were maintained. The ensuing rapid decline in abundance was not noticed and ultimately stocks collapsed.

One of the most influential attributes leading to the collapse of stocks is this change in catchability and it is argued that such changes may be the result of behavioural processes involved in schooling. The influence of such processes on the spatial structure of herring stocks is unclear.

My thesis proposes three avenues of study for considering options to reduce the variability in fisheries on small schooling pelagic fish. The first objective is to provide a better understanding of the spatial structure of populations of schooling fish. The work will be focused on herring, and my proposal is to use a modelling approach to develop an understanding of the spatial structure and processes operating at the school level and influencing the stock at a mesoscale level (spatial scale, km to10's of km; temporal scale, weeks to months). To explicitly consider different life history stages, the model will be separated into three components (Figure 1): (1) ocean feeding phase, (2) overwintering, and (3) spawning.
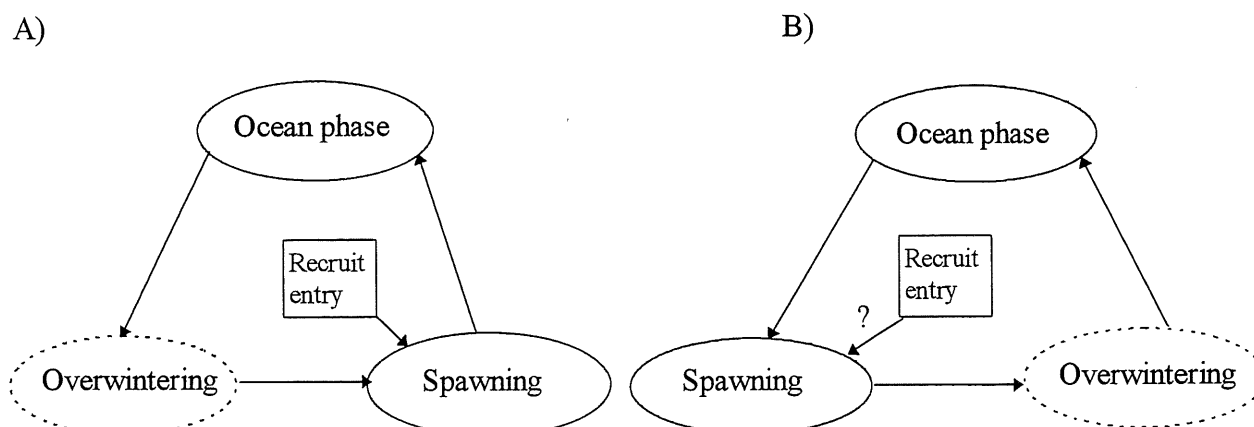
A)   B)

Figure 1. Conceptual diagram of (A) spring and (B) autumn-spawning herring populations (dotted line indicates that the stage does not occur in all populations).

Information on size, distribution and density of schools, and the factors governing the observed dynamics, collected during this cruise will be of considerable value in developing the 'ocean phase' model. Previous studies on the spawning grounds will similarly be useful in the development of the 'spawning phase' model. In addition, comparisons with the spatial structure of Pacific herring should help interpret adaptiveness of such behaviours; for example, understanding the observed major shifts in spatial pattern that have accompanied marked changes in abundance of herring.

The first step required in development of the model is the identification of attributes that may affect stock dynamics. Table 1 provides a provisional list of such attributes for each phase of the model. The influence of these attributes will be combined so as to produce a pre-determined spatial structure of stock distribution characterized by stock size and range, school size, inter school distance and pattern, distribution and depth change regime. Dependent on time scale, movement dynamics may also be incorporated. Change among the attribute set will lead to a corresponding change in the spatial structure of the stock. For the purpose of developing the pre-determined spatial stock structures it will be necessary to gather information regarding the response of the spatial dynamics of herring to the influence of the selected attributes. Such 'responses' can be classified as three fundamental categories: what, where and when. Figure 2 provides an example of a 'where-when' matrix used for identifying the influence of attributes on spatial structure of schools.

For each phase, attributes may be weighted to account for the dominant motivational state. For example, during the ocean phase, feeding attributes may have a greater influence on the dynamics driving stock structure than in the overwintering phase, during which herring are not so highly motivated to feed. It is proposed that the model stock will move between each stage with a discrete time step and then remain within that phase for a series of time steps during which the stock may: change in spatial structure, corresponding with changes among attributes; be depleted (by fishing and natural mortality); or grow (by recruitment). Spatial distributions can be mapped, generically, for each step of the model.

Table 1. Possible attributes influential in determining the spatial structure of herring stocks.

Model Phase	Hierarchy of attributes influencing spatial structure of herring stocks														
	Feeding attributes *				Predation attributes*					Maturation attribute	Environmental attributes			Fishing attributes	
	Food distribution / level of aggregation		Food type		Predator distribution		Predator species			Gonad ripeness	Temperature	Salinity	Spawning substrate	Pressure	Distribution of effort
	Vertical	*Horizontal*	*Size*	*Species*	*Vertical*	*Horizontal*	*Fish*	*Mammals*	*Birds*					*Number herring removed*	
Ocean	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓	✓
Over-wintering	?	?	?	?	✓	✓	✓	✓			✓			✓	✓
Spawning	?	?	?	?	✓	✓	✓	✓	✓	✓			✓	✓	✓

✓ attribute considered influential at this stage; ? unsure as to atrribute influence; * May change with respect to time (e.g. seasonal)

Surface

WHERE
- Spatial scale (depth in meters)

Bottom

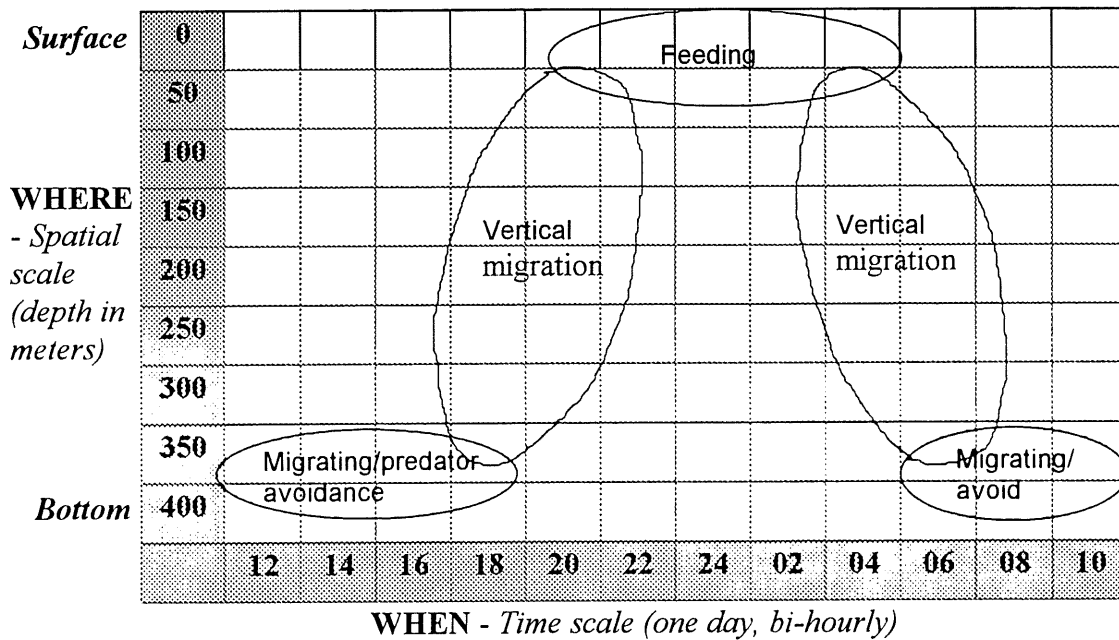|	0					Feeding						
	50											
	100											
	150				Vertical			Vertical				
	200				migration			migration				
	250											
	300											
	350		Migrating/predator						Migrating/			
	400		avoidance						avoid			
		12	14	16	18	20	22	24	02	04	06	08	10

WHEN - *Time scale (one day, bi-hourly)*

Figure 2. Example of a where-when diagram, indicating some spatial and temporal dynamics in herring schools during ocean phase.

The second objective of my thesis combines with information from the first and proposes to examine the ways in which knowledge of the spatial structure and dynamics of herring stocks may be implemented in developing better systems for the regulation of harvest strategies designed to achieve fixed harvest targets. In particular, it will focus on harvest tactics in the British Columbia roe-herring fishery. Further to this, policy options for harvesting will be examined under a decision analysis framework to determine the 'overall benefit to society' of any given policy option.

Somewhat to aside, but relevant to harvest policy options and management of herring fisheries in general, I propose for a third objective to examine the utility of an ecosystem simulation model (ECOSIM - an extension of the ECOPATH II ecosystem model) for providing a better understanding of ecosystem driving forces that may help explain the nature of the observed variability associated with populations of schooling fish. Information gathered as a result of the *Mare Cognitum* programme will be useful for developing a fuller understanding of such forces.

Note on ECOPATH II ecosystem modelling

ECOPATH II provides a structured format for the development of an ecosystem model built on the underlying principle of mass balance (since the system exists in nature, the processes throughout the system must balance). ECOPATH II is by no means a simple 'food web' diagram. Its models are built with detailed information (from literature and/or field work) regarding biomass, consumption rates and productivity of all the system components or groups thereof. Given the structure of the ecosystem, ECOPATH II quantifies the ecotrophic efficiencies (flows of energy) through system components that are required to maintain the ecosystem under the mass balance principle. Imports to the system (such as input nutrients from a river) and exports from it (such as removal of fish due to fishing) can be fully quantified. Respiration rates are also calculated. The trophic structure for each of the system components is calculated based on the average trophic level of prey items for that component. ECOSIM is a new development that enables the user to explore the effects that changes in the balance of the ecosystem may have on trophic flows and consequent ecosystem structure. By the provision of a little insight, ECOSIM may thus provide a useful tool to fishery managers required to manage under the intuitive, but otherwise impractical, 'ecosystem management' principle.

COST/BENEFIT FUNCTIONS AND FISH SHOAL SIZE

Taja Lee (Fisheries Centre, University of British Columbia)

Fish schools were once viewed as egalitarian, leaderless societies in which cooperation preserved the species (e.g. Radakov 1973). In contrast to such group-selectionist views, during the last few decades much effort has been put into revealing the behavioural rules of shoaling and schooling behaviour (reviewed by Pitcher & Parrish 1993). Insight of fish shoaling and schooling behaviour has come from a perspective that examines the costs and benefits to individuals. Much of this work has been done in artificial environments in small aquaria and tanks containing a small number of fish. Extensive laboratory evidence shows that fish shoaling behaviour is driven by individual decisions of fish to join, leave or stay 'JLS' with a group, and these decisions are largely determined by trade-offs between the availability of food and the perceived risk of predation (Pitcher & Parrish 1993). More recent fisheries acoustic work has also allowed detailed observations of the natural dynamics of commercially important fish schools, particularly that of Norwegian spring-spawning herring (e.g. Misund et al. 1995). These studies have shown that the form and structure of herring schools are dynamic, changing in relation to other herring schools, predation risk, spawning stage and activity (Pitcher et al. 1995, Nottestad et al. 1996). The observed dynamics of joining and splitting could help adjustment of herring school size to prevailing conditions.

A simple simulation model (SKOOL) was presented during this cruise. The aim of the model is to simulate fish shoal size based on JLS rules. In the model, the size of shoal in which an individual fish occurs is simulated for each time step. A fish changes its swimming direction and speed after each time step based on two decisions: stay/join and leave. If a neighbouring fish is positioned within its sensory area, the influenced fish decides, based on a cost/benefit function, whether it is beneficial to be in a shoal size which includes that fish. If so, the influenced fish "joins" the neighbour by taking the average of its and the neighbour's swimming directions and swimming speeds. If not, the fish "leaves" the neighbour by taking a swimming direction perpendicular to the swimming direction of its neighbour. Results include a comparison of the distribution of group sizes with and without predation threat. The key to this model is the cost/benefit, or essentially, fitness function. Confusion over the 'optimum' shoal size in the cost/benefit function arose in the cruise presentation. A clarification of the cost/benefit function follows.
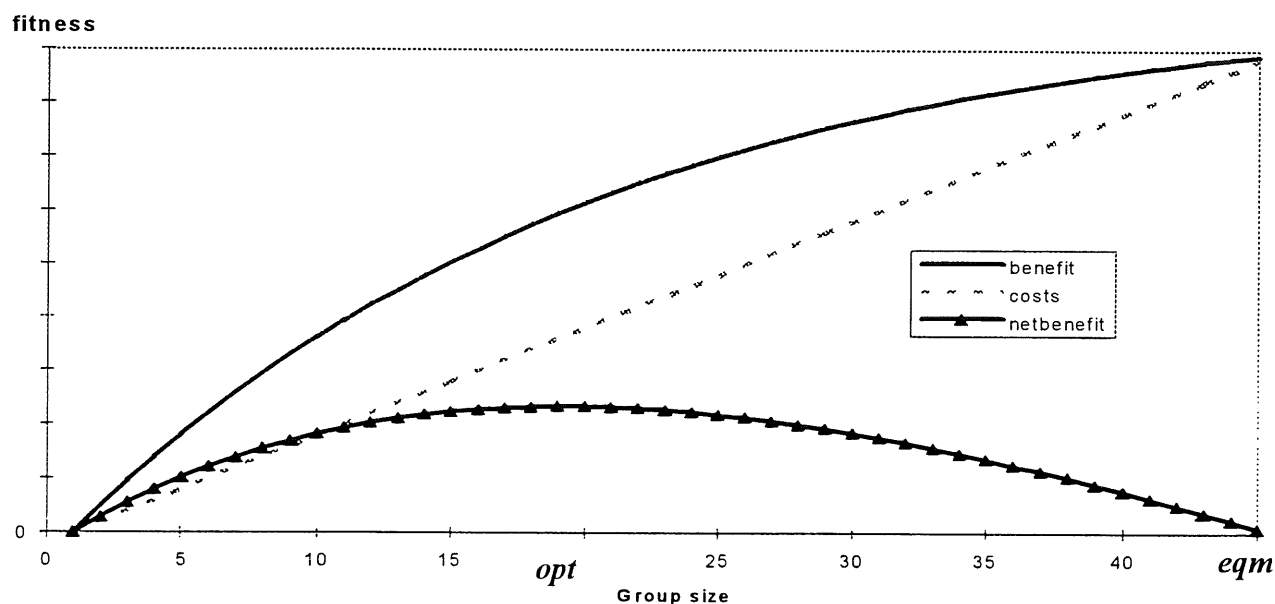
Figure 1. A hypothetical cost/benefit function with the resulting net benefit (fitness) curve. The 'optimal' groupsize (*opt*) is where the net benefit is at the maximum and the equilibrium group size (*eqm*) is where the net benefit is equal to 0 (or the same as being in a group of 1).

Benefits, such as faster location of food, increase with shoal size. Costs, such as intraspecific competition, increase with shoal size as well. A simple cost/benefit analysis suggests that there will be an optimal group size where the net benefit is at a maximum (*opt* in Figure 1). In the best of possible worlds, we would expect to find groups of this optimal group size in the wild. However, what is "best" is the behaviour that maximizes fitness. A principle of behavioural ecology states that animals do not sacrifice their own fitness for the good of their group (e.g. Grafen 1984). Various models (e.g. Clark & Mangel 1984) indicate that this optimum group or shoal size is unstable and that group sizes in natural systems are considerably larger than optimal. This is because individuals do better in a group (even an oversized group) than on their own. This hypothesis predicts that we should observe groups in which the average net benefit is zero (an equilibrium, *eqm* in Figure 1) rather than a maximum. One clear observation from the cruise sonar data is that this optimal and equilibrium shoal or school size is dynamic, changing with time of day (related to depth of plankton layer, i.e. food), perceived predation risk (be it whales or watermelons) and motivational state (hunger vs spawning). Perceived predation risk, for example, is modelled as an increase in the benefit curve, where larger number of fish in a school reduces risk of capture, increases confusion and permits more effective evasion of predators. This model may be extended to include foraging success and hunger.

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Daily record of activity

-Canadian and English guests arrived 1/4 and 2/4, Norwegian personnell onboard 3/4 by 13:00. Geoteam engineer onboard to mount Starfix DGPS.

-Departure 17:00 to Vigrafjorden to test Starfix, it did not function, went out Breisundet to Sildestøbotnen, but Starfix still did not function, went back to Ålesund with the engineer, from Ålesund 21:00, sailed the inshore ship-line northwards because of western storm.

-Cruise meeting 18:00, presented cruise plan, and set up watches, Vebjørn presented results from Cruise no. 4.

4/4

At Halten lighthouse at about 12:00, headed north-north west towards 67° N, 5° E. H. Hammer made Starfix DGPS function by using an appropriate 24 V power supply as specified (the Geoteam engineeer used 12 V). Scientific meeting at 14:00, presented our results on school dynamics from 1994. Increasing wind and waves, had to reduce the speed at 17:00 because of strong gale. Maneouvring against the wind during the evening and night.

5/4

Little storm (44 knots), vessel turned against the wind, people writing or reading.

6/4

Wind decreased during the night, started moving towards position 67° N, 5 E° at 05:00.

Activity: CTD 196 (7.2°C in surface), CTD 197 (6.0°C at surface), MOC 197, PT 213 (no catch), PT 213 (216 kg herring, 0.2 kg blue whiting, 2.9 kg saithe, 1.9 kg redfish, 0.7 kg haddock), PT 214 (surface, 2 herring + 2 blue whiting)

7/4

Breeze, heading west along 67° N.

Activity: CTD 198 (5.7°C at surface), CTD 199 (5.7°C at surface), PT 215 (surface, no herring), PT 216 (50-110 m, no catch) sonar-guided trawling on significant and distinct school recordings at 40-80 m depth, probably schools of blue whiting that seemed very sensitive to the vessel, dived and split when the vessel approached, PT 217 (275 m, catch: herring + blue whiting), meeting 18:30, MOC 200, PT 218 (75 m, no catch, just 1 specimen of blue whiting, extended layer, strong trawl avoidance, saw many shoals that avoided sideways in front of the trawl doors), PT 219 (75 m, sonar guided trawling on 2000 m² school that moved south, catch 2.5 tonnes of herring, pos: 67° N, 00° 00' 02" W).

8/4

Breeze, heading west along 67° N to 3° W, turning to 30° at 10:00.

Activity: MOC 201, CTD 201 (5.0°C at surface, 1.7°C in 300 m), MOC 202, CTD 202 (pos 67° N, 2°21' W, 2.5°C at surface, 2.5°C at 300 m). No recordings between 67° N and 68° N, CTD 203 at 68° N, 1° 30' W, 3.7°C at surface, 1.3°C at 300 m, meeting 18:30, east along 68° N, CTD 203, MOC 204 (68°N, 00° 30' W), recorded about 20 schools close to surface from about 1° E to 3° E.

9/4

Eastern little gale.

CTD 205 (68°N, 4°E, 5.2°C at surface, 4.2°C at 300m), PT 220 at single school recording in 70 m which we did not find again, catch 5 kg blue whiting, heading 330° from 68° N 5° E, PT 221 at single school recording, found the school which avoided the trawl, no catch. CTD 206 at 68° 30' N (5.1°C at surface, 4.1°C at 300 m), meeting 18:30, heading west along 68° 30' N, MOC 207, PT 222 (blind haul at surface, no catch), no recordings along 68° 30' N.

10/4

Eastern little gale.

CTD 208 at 68° 30' N, 1° 02' E (4.9°C at surface, 3.9°C at 300 m), heading south 210°, successful tracking of school 1 at about 68° 09' N 00° 14' E, school at 300 - 400 m, tracked for 1 hour, substantial school dynamic with up to 3 school units in the beam simultanously, PT223 aimed at position of last contact of the school, trawl in 350 m, catch 1 school, catch about 1.5 tonne herring with substantial stomach content. MOC 210, CTD 210 in position of school tracking (4.1°C at surface, 1.6°C at 300 m), tracking of school 2 (1 hour), PT 224, tracking of school 3 (1 hour),

11/4

Eastern little gale.

Tracking of school 4, PT 225, catch 100 herring, MOC 211, CTD 211 (5.1°C at surface, 2.5°C) at 300 m. Tracking of schools 6-8, schools heading south-west, speed 0.37 m/s, sustantial dynamic with joining and splitting, PT 226, catch 2 tonnes of herring, MOC 212, CTD 212 (5.6°C at surface, 3.0°C at 300 m), tracking of schools 9-12 in position 67 41N 00 07W, school 12 moved 250 m north in 30 min, PT 227, MOC 213, CTD 213 (5.6°C at surface, 3.8°C at 300 m), tracking of schools 13-16.

12/4

Breeze, good conditions, tracking of schools.

Continuing school tracking along 00°, tracking of schools 17-19, PT 228, catch 57 herring, MOC 214, CTD 214, tracking of schools 20-26, schools moving south-east, speed 0.35 m/s, PT229, catch 124 kg herring, MOC215, CTD215, tracking of school 27-29, PT 230, Catch 2.5 tonnes of herring, MOC 216, CTD 216, meeting 18:30, cruising to 67 N, then west. Tracking school 30, 67N 00 05E, 1500 m in 1 hour, 131° heading.

13/4

Breeze, good conditions.

PT232 at surface, catch 1.5 bucket (30 kg) of herring, MOC 217, CTD 217, heading west along 67° N, recording schools at surface for study of spatial distribution during the night, tracking school 31-35 when schools descending during the morning. PT 232 at 325 m, catch 1 tonnes of herring, MOC 218, CTD2 18 (4.8°C at surface, 2.0°C at 300 m), tracking school 36 for 15 min, school part of extended dense layer at 325 m, computer breakdown, heading west along 67° N, no schools west of 1° W, continuing to 1° 25' W, CTD 219, 4.8°C at surface, 3.5°C at 300 m, continuing westward, no recording of herring schools. CTD 220 at 67°N, 2° W, 3.1°C at surface, 2.4°C at 300 m, turning eastwards again, tracking school 37, 38 at about 1° 20' W, 67° N which probably is the most westward schools recorded, observations of 12 finwhales in the area, PT 233 at 350 m, catch 2 tonnes of herring, MOC 221, CTD 221, 4.3°C at surface, 2.6°C at 300 m, chasing group of 4 finwhales with vessel slowly (5-6 knots) approaching and with EK500 and SA950 off, recorded the whales on SA950 after about 45 min chasing when about 350m in front of the vessel, the whales passed near a school which we tracked as no. 39, the school rose to the surface and dispersed, tracked also school 40 around midnight,

14/4

Breeze, good conditions.

PT 234 at surface, catch 8 buckets of herring, MOC 222, CTD 222, 4.2°C at surface, 2.0°C at 300 m, tracking school 41, possible whale chasing of the school, tracking school 42-44 at about 67°N 00° 40' W, PT 235 at 350 m, catch 1 bucket of herring, MOC 223, CTD 223, 5.2° C at surface, 2.0°C at 300 m. Stopping school dynamic investigations and heading 185° south from 14:00 to 62° N to investigate northern EU-waters for presence of Norwegian spring-spawning herring. Started working on the cruise report. Meeting 18:30.

15/4

Southern little gale during the night that decreased during the day, steaming south towards EU-waters north of Shetland, PT 236 at 350 m, catch 1 bucket of blue-whiting, meeting 18:30.

16/4

Southern little gale.

PT 237, catch, 1 bucket of blue-whiting, PT 238, catch 1 bucket of blue-whiting, PT 239, catch 10 buckets of 15-22 cm one-year-old blue-whiting, meeting 18:30.

17/4

Southern gale.

Conducting environmental sampling at the Svinøy transect. Sum up - meeting 18:30.

18/4

Arriving Bergen harbour at about lunch time.