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Evaluation of the Norwegian Shrimp Surveys conducted in the Barents Sea and the Svalbard area 1980-1997.

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ABSTRACT

Trawl surveys for shrimp (*Pandalus borealis*) have been conducted annually in the Barents Sea and the Svalbard area since 1980 by Norwegian research institutes. The surveys have been conducted in the period April to September for a duration of 25 to 97 days each year. Until 1992 the Institute of Marine Research in Bergen (IMR) carried out the investigations, and thereafter the Norwegian Institute of Fisheries and Aquaculture Ltd. (Fiskeriforskning) in Tromsø has been doing the work. All together four different vessels have been used.

The trawl used for sampling, a 1800 meshes modified commercial trawl, has been the same throughout the period, although with modifications of both the ground gear and the rigging. The modifications have had a considerable influence on sampling performance over time.

The study area in Svalbard is stratified according to depth and latitude while the study area in the Barents Sea is stratified based on geographical areas of assumed homogenous density of shrimp together with a subjective division of the area into fishing grounds.

Three different approaches to survey design have been used - random stratified trawl stations, fixed trawl stations in a modified regular grid within a stratification of the area and fixed trawl stations in a depth stratified system. A study has been undertaken to calculate an optimum sampling density with respect to a desired level of precision.

The survey data are primarily used to calculate indices of shrimp abundance, both for the whole area and for a set of sub areas. Data on carapace length distribution is used to separate age groups and to study size and growth of the year classes in different sub areas.

INTRODUCTION AND HISTORY

Since 1992 the Norwegian Institute of Fisheries and Aquacultre Ltd. (Fiskeriforskning) in Tromsø has had the national responsibility for the research on shrimp (*Pandalus borealis*) north of 62°N. The research is done in close cooperation with the Norwegian College of Fisheries Science at the University of Tromsø. There is also a close scientific cooperation with the Institute of Marine Research in Bergen (IMR) which in the period 1980 - 1991 conducted the shrimp research in the Barents Sea and the Svalbard area, i.e. the Norwegian, Russian and Svalbard Exclusive Economic Zones (EEZ's) north of 62°N. The Polar Research Institute of

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Marine Fisheries and Oceanography (PINRO) in Murmansk, Russia, has conducted shrimp surveys in the same areas jointly with the Norwegian institutes since the mid 80's.

The shrimp fisheries started in the area in 1970 as Norwegian vessels explored new fishing grounds. Russian, at that time Soviet Union, vessels first fished for shrimp in the area in 1974. Both countries increased their catches in the years to follow and a few more countries involved themselves in the fisheries (Fig. 1). In 1984 the total catch reached an overall maximum of 130,000 t. A subsequent reduction in catches down to 45,000 t in 1987 was probably caused by reduced abundance of shrimp in the area. An increase in the catches took place until 1990 giving peak catches above 80,000t. In the later years, i.e. 1994, 1995 and 1996 the catches have been even lower than in 1987 with values well below 40,000t. The Russian catches show the largest proportional reduction.

All shrimp (*Pandalus borealis*) stocks except the stocks in the Barents Sea and Svalbard area and at the Flemish Cap are managed by a TAC (Total Available Catch). At the Flemish Cap and in the Svalbard area the shrimp fisheries are regulated by number of effective fishing days. In the Barents Sea and the Svalbard area the fisheries are regulated by smallest allowable shrimp size (15mm carapace length), limited number of young fish allowed in the catch and by number of vessel licenses given.

The Joint Norwegian-Russian Fisheries Commission has asked ICES to include the shrimp stocks in the Barents Sea and Svalbard area into an adequate working group with annual meetings, preferably the "Arctic Fisheries Working Group". Since the status of the shrimp stocks is also important in view of shrimp being an important food item for cod there is a need to assess shrimp and fish stocks in a multi-species perspective. In the later years it has become clear to everyone working with fish stock assessment that reliable indices of abundance from surveys are as important as reliable catch statistics in order to give good stock assessments and to forecast the stock and catch in the future.

From the surveys carried out for shrimp in the area, detailed information on the status of the stock is given in annual reports presented in various scientific forums, both by Norwegian authors (Tavares 1980, Teigsmark and Øynes 1981, 1982, 1983a, 1983b, Hylen *et al.* 1984, Tveranger and Øynes 1985, Hylen and Øynes 1986, 1988, Hylen *et al.* 1987, 1989, Hylen and Ågotnes 1990) and by Russian authors (Berenboim *et al.* 1986, 1989, 1990, Mukhin and Sheveleva 1991). Several joint reports have also been submitted (Berenboim *et al.* 1991, Aschan *et al.* 1993, 1994, 1995, 1996).

The purpose of the Norwegian shrimp surveys is to provide data for estimation of trends in the abundance and biomass of the shrimp stock. This includes the necessary sampling to provide data on the length distribution of shrimp, which is needed to estimate the proportion of the different year classes. An additional purpose of the surveys has been to provide samples of fish species to be used in general ecological investigations, and to some extent, to provide abundance indices for these species.

TECHNICAL DESCRIPTION

THE SURVEY AREA

The survey area covers the known fishing grounds for shrimp. Based on additional knowledge from other surveys, areas where shrimp is not found are excluded from the survey area. As the areas of fishing have expanded into waters covered by ice during the last years, the survey area has been extended accordingly. This has been possible with the use of the research vessel "Jan Mayen" designed to operate in ice covered waters.

Traditionally the areas denoted as the Barents Sea have a sea bottom where depths are relative homogenous over large areas. The shrimp are found at depths between 200m and 400m. The areas denoted as Svalbard are characterised by a narrow continental shelf and the main shrimp areas found on the steep slope of the shelf from 200m to 500m depth. The two different topological areas calls for different stratification to be used. The survey area is 47732 nm² in the Barents Sea and 21548 nm² in the Svalbard area.

THE STRATIFICATION

In the Barents Sea the area is stratified by enclosing each main fishing ground in a separate strata. The rest of the seabed is divided according to a subjective evaluation of the topography and size of the strata. In the Svalbard area the stratification is done by allowing the depth intervals 200-300m, 300-400m and 400-500m in each latitude interval of one degree to constitute the main strata system. In addition the southern and northern latitude intervals have been divided in eastern and western strata.

The stratification of the Barents Sea and Svalbard area have developed gradually over the years into the systems presented in Figures 2 and 3, allowing renumbering and some minor adjustments of boarders to take place over time.

In view of advice on size of strata and for other practical reasons, the strata have been combined into main areas denoted as areas A to H, with the addition of areas I to K in the Russian EEZ (Fig. 4). The estimates of indices of biomass for the years 93 to 97 are given for each of these main areas and as a combined total.

SAMPLING DESIGN

As seen in Table 2. the Barents Sea survey has been conducted in the period April to May while the Svalbard survey has been conducted in the period June to September. The grate difference in timing of the cruise in the Svalbard area may effect the index of biomass. In the 80's trawling was conducted during day light but since 1991 trawling has been performed day and night.

In the early period of the surveys, i.e. the 80's, the trawl stations were selected by dividing each strata into small rectangles, usually 5 x 5 nautical miles, and selecting a certain number of rectangles by a random selection process. The actual trawling was then allowed to be taken anywhere within the selected rectangle. The number of stations selected, was usually proportional to the area of the strata. However, some increase in number of stations in strata with excepted high abundance (app. 9 % of the squares covered) and reduced number of stations in strata with excepted low abundance (app. 5 % of the squares covered) (Teigsmark and Øynes, 1981). Usually the total number of trawl stations was 120 in the Barents Sea and 70 in the Svalbard area during the 80's.

The above sampling design caused a lot of sailing time between trawl stations and during the late 80's a strategy involving a systematic grid of trawling positions was developed. This system was first introduced in the demersal fish surveys in the Barents Sea, but since 1991 it has also been used for the shrimp surveys in the area.

In the Barents Sea grids of various density have been used, but generally the distance between trawl positions has been 20 nautical miles. In some areas a 10 nautical mile grid has been used for experimental purposes. The accuracy and precision of the estimates obtained by this sampling strategy has been evaluated by Harbitz *et al.* (1997) and a grid of approximately 28 nautical miles seem to give an acceptable result. This reduces number of stations in the area from 120 to 90 in the Barents Sea. The grid of 28 nautical miles was used in the Barents Sea in 1997 and the survey track is shown in Figure 5.

In the Svalbard area a systematic grid is not applicable as the trawl position must be fixed according to the depth. However, a semi-systematic approach has been developed by sampling the same stations each year. To some extent to many stations have been sampled and during the last years a reduction in stations has taken place. App. 80 stations are now needed to cover the total area of Svalbard where as app. 160 stations were used in the early 90's. An evaluation of the accuracy and precision of the Svalbard estimates has not been done yet.

BIOLOGICAL SAMPLING

The biological development of shrimp is divided into several stages. Shrimp starts of as males (Stage 2) after the juvenile stage (Stage 1). Thereafter they reach intersex (Stage 3) before they develop into females with headroe (Stage 4). When the females mate, the roe is moved under the abdomen (Stage 5), where it stays until hatched (Stage 6). Some females then take a resting period (Stage 7) but others start on a new cycle with headroe (Stage 8). The characters, the Russian and the Norwegian coding of the stages are given in Table 1 (Aschan *et al.* 1993).

Crustaceans usually have no hard, bony tissue that they bring with them through moulting and therefore direct age reading is not possible. Cohort analysis of length frequencies where modals of the distribution forms the age groups (year classes) are used. In order to obtain useful results the carapace length of app. 300 individuals from each trawl station is measured.

SAMPLING TRAWL AND RIGGING

A detailed control scheme are filled in when the trawl is introduced and when maintained (Fig. 6). Schemes describing the rigging of the trawls are filled in for the trawls in use, when the survey starts and every time changes in the rigging are performed (Fig. 7). The sampling trawl is a small shrimp trawl equipped with a ground gear. Various gears, otter-boards (trawl doors) and cod-ends have been used through the period (Table 2). The development of the trawl has been adjusted to suit the needs of the research on cod and other demersal fish species (Engås 1991). However, in the 90's changes have been introduced to gain the shrimp research.

Originally the trawl is an 1800 meshes shrimp trawl with the following specifications; 30m headline, 19m groundrope and 80-42mm knot to knot stretched mesh size in the body (Fig. 6). The mesh size of the cod end has been stable with 42mm knot to kot stretched mesh. In 1986 a four m inner net of 10mm stretched mesh size (center to center) was introduced. In 1994 it was replaced by a 15m inner net with 20mm mesh size (Table 2). Bridle arrangements have been the same with 40m upper and lower bridles.

In the 80's the 19m long gear was composed of 18 inches light weight rubber wheels in the mid section and 18 inches light weight rubber half spheres in the side sections. Since 1987 a "Rockhopper" gear has been used. A scheme for the maintenance of the gear is shown in Figure 8. This gear is designed to avoid loss of small cod under the gear. This is due to a better ability than the former rubber bobbins gear, to stay close to the bottom when the gear encounters small rocks and bumps on the sea bed. This improvement is also beneficial when catching shrimp.

A problem with this trawl and gear combination was that it easily dug into the sea bed and filled the trawl with mud and clay on soft clay and mud bottom. This resulted often in loss of parts of the trawl. The reasons for the "digging" are too large spread between the doors leading to a very tight stretch in the gear followed by, a tendency of the chains at the gear to dig into the clay, a too heavy gear and the construction of the belly. The problem was solved by four adjustments. A 24m rope connecting the warps app. 80m above the doors ("strapping") constraining the spread of the doors to app. 47m and the vertical opening of the trawl to app. 5m. The chains were equipped with two 18 inch steel bobbins each, 40 floats were attached to the fishing line and 15 on each side along the belly to reduce the weight of the trawl in the sea. The result of this is that there is almost no damage to the equipment during the survey, compared to earlier when up to 5 trawls were needed to conduct a 3 week survey.

Three types of otter-boards (trawl doors) have been used through the period. In the 80's Waco combination doors (1500 kg), for both bottom trawling and pelagic trawling, were used. In the 90's traditional "Steinshamn" V10-doors (2050 kg) for bottom trawl have been used. In 1994 "Steinshamn" W9-doors (2050 kg) with four point connections were replacing V10-doors with two point connections since they kept a much more stable door-spread (Fig. 9) (Kristjansson, 1994).

In order to monitor the vital geometry of the trawl, distance measures are made using sensors mounted to the doors, to measure the distance between the doors, and on the headrope, to measure the height of the trawl and the bottom contact of the gear.

Selectivity and Efficiency of the Trawl

The mesh size in the codend (20mm stretched mesh) keeps all size of shrimp within the codend, but small shrimp has a tendency to escape through the meshes in the belly of the trawl(40mm stretched mesh). There is also a substantial loss of small shrimp under the fishing line (Larsen *et al.* 1993). In order to investigate the size selection of the trawl, small meshed bags were attached to the trawl on the wings, belly and codend as well as between the gear and the fishing line (Hafsteinsson *et al.*, in prep). As a result of these investigations a small meshed bag is attached to the lower belly as a standard equipment since 1995 (Fig. 10) (Nilssen *et al.* 1986). The sample of small shrimp obtained in this bag gives an additional index of abundance of the smallest shrimp and provide data on the size of the first age groups.

The efficiency of the survey trawl was investigated by comparing the trawl with a specially designed shrimp sampler (Larsen *et al.* 1993). The shrimp sampler is a 3m wide and 8m tall steel frame, with an array of small meshed (10mm stretched mesh) bags placed at different heights above the bottom (Fig. 11 and 12). The comparisons show that there is a considerable loss of shrimp in using the sampling trawl, compared to what is obtained using the special shrimp sampler. The length distribution is significantly different as the small shrimp is almost absent in the trawl.

VESSELS USED DURING THE PERIOD

From 1980 to 1991 the 48m research vessel "Michael Sars" owned by the Institute of Marine Research in Bergen was used. This vessel used the combination doors without "strapping". Until 1987 the rubber wheel gear was used, later the "Rockhopper" gear was used.

In 1990 the hired 51m motor trawler "Anny Kræmer" was used in the Svalbard survey with V10-doors but otherwise the same trawl and gear as R/V "Michael Sars" in the same year.

In 1992 the hired 47m motor trawler "Gargia" was used for both surveys. The trawl doors used were V10-doors and this year the "strapping" was first used. Also some experiments with floats on the gear were done.

From 1993 onwards the 64m research vessel "Jan Mayen", hired from the University of Tromsø, has been used with W9-doors, "strapping", floats on the gear and bobbins on the chains.

RESULTS OBTAINED FROM THE SURVEYS

As mentioned before, annual survey reports has been published as ICES papers. There are two main results obtained from these surveys. First are the indices of biomass in each main area, and as a total, from 1982 until 1997 (Table 3). The second is a detailed knowledge of the life history of the northern shrimp in the study area, including length frequency distribution, growth, maximum length and size at maturity within each main area and as a total (Teigsmark 1983 and Aschan and Nilssen in prep.). Genetic (Allozyme and RAPD) analysis have been performed since 1995 with the aim to define management units within the Barents Sea and Svalbard area (Martinez *et al.* 1997 and Drengstig *et. al.* 1997). However, no distinct genetic units are defined yet and the work will be followed by identifying mother populations by studies on larval development and dispersal.

Secondary results obtained are information on the behaviour of the sampling trawl with respect to shrimp and other demersal fishes (Hafsteinsson *et al.* in prep, Larsen *et al.* 1993) and technical information on optimal rigging of the trawl (Kristjansson 1994, Engås and Ona 1993).

Since the sampling and registration include all species in the trawl, valuable data on Long rough dab (*Hippoglossoides platessoides)* and Greenlad Halibut (*Reinhardtius hippoglossoides*) has been collected and results have been reported by Albert *et al.* (1994 and 1997). The data has also been used when mapping the geographical distribution and density of all available fish species (Aschan *et al.* 1994).

DISCUSSION

As the purpose of most surveys of this kind is to produce an index of abundance or an index of biomass, the Norwegian surveys for shrimp in the Barents Sea and the Svalbard area fully answer this purpose. However, the sharpest critique to be raised against the survey is that these results are not used in an assessment framework. From this point of view it is therefore very difficult to evaluate the quality of the produced series of indices, since they are not comparable to an actual assessment of the shrimp stock.

The objective of the survey is to produce an index that fully reflects the stock in its trends over time. The evaluation of how well the survey meets the objective can, based on the above mentioned conditions, only be measured in relation to how this survey performs relative to other surveys. The parallel development of the shrimp survey and the other Norwegian surveys conducted for demersal fish in the same areas should ensure that the surveys perform equally. The special adaptations in survey design done to improve the performance in relation to shrimp are well documented and evaluated and should therefore imply an improvement of the survey.

An argument against this is that all this improvement may very well have increased the efficiency of the survey to an extent that the indices in the early period are not comparable to the indices in the later years. This kind of argument goes for most surveys that have been through some technical improvements. In this connection the Russian shrimp surveys give us valuable data as they are conducted in the same period and the trawl and gear has had minor changes over time. Parallel trawling has shown that the Russian trawl has a higher catchability when the abundance is high (> 100 kg /nautical mile) (Mukhin and Shevaleva, 1991). However, the overall catch rates are fairly comparable.

At present the cost of conducting a survey in relation to what is gained is of great concern. Work is undertaken to investigate the effects of reducing the number of trawl stations and hence the time needed to conduct the survey (Harbitz *et al.* 1997). The number of crew is usually 7 and the days spent every year is between 40 and 50 days at sea. The cost of a vessel is also substantial, US$ 12,000 pr day.

Cost reduction may be accomplished in two different ways; reducing the time and personnel or sharing the time and personnel with other investigations. Preliminary results indicate that it may be possible to reduce the number of days needed to 25 for getting an index for abundance. This is partly due to improved accuracy and lower haul to haul variation in sampling gained by better trawl performance. However, variation in biological development and growth may require more sampling in certain areas.

Improved computer facilities for gathering and storing data may also reduce the need of manpower to some extent. However, the cost of developing good automated systems for gathering and storing data are substantial and it is difficult to argue for the potential gain of these large investments.

Improved sampling of juveniles would make it possible to calculate recruitment indices. The efficiency of the small meshed bag attached to the belly is not known. Strong currents may lay the bag against the belly and prohibit shrimp to pass into it. The introduction of the shrimp sledge as an additional sampling gear would provide excellent data. However, this would require more sampling time at each station. On the other hand, there is a potential for correcting the selectivity of the trawl with the use of correction factors to calculate the "true" size distribution with respect to what is actually in the sea.

Based on the above given critique one could say that the trawl used is not adequate for the goals sought. There is some work going on in order to design a complete new more robust trawl with smaller mesh size and higher opening.

Large variations of the catch rates are observed and are not fully explained by changes in biomass over time and area. It is known that currents, water temperature and light may influence the distribution of shrimp and monitoring these parameters may be important. To day temperature is measured using a sensor attached to the trawl and light is measured at the surface. There are sensors available to be mounted on the trawl to measure current speed and direction. This is a necessary supplement to the use of Acoustic Current Doppler Profilers (ADCP) to measure the current in the water column as the ADCP does not measure the current closer to the bottom than 15% of the depth.

The potential future use of this survey is to include the results in an assessment framework for shrimp. Such a framework need additional catch data, but the data from the survey will constitute the main source of information. Different models including predation has been considered. Such models are the stock production type model evaluating the offshore *Pandalus borealis* stock of the North Icelandic waters (Stefánsson *et al.* 1993) and a model introduced by Cook (1995).Work has been started to develop a model based assessment framework in where both data and models describing the relationships between various sources of data and variables are to be included. Some attempts have also been made to construct a multispecies VPA including shrimp (Berenboim *et al.* 1991) which may prove successful.

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Table 1. Sex stages of shrimp *Pandalus borealis* with characteristics and the Russian and the Norwegian codes in use.

Sex stage	Russian code	Norwegian code
Male	Male	2
Transitional (intersex, Norway) - no headroe - with spines	Transitional	3
Female, first time spawner (intersex, Norway) - headroe - with spines	Female 1+, 1-3	4
Female spawned - outroe - no headroe - no spines	Female 2, 0	5a
Female, eggs spawned - outroe - headroe	Female 2, 1-3	5b
Female, larvae just hatched - setae, eggrests - no headroe	Female 3, 0	6a
Female, larvae just hatched - setae, eggrests - headroe	Female 3, 1-3	6b
Female resting stage	Female 0	7
Female second time spawner - Headroe - no spines	Female 1-, 1-3	8

Table 2. Year and area of survey, vessel used, depature date, number of survey days, towing distance, meshsize of cod end, canges in rigging of trawl and references for the shrimp surveys conducted in the Barents Sea and Svalbard area.

Year	Area	Vessel	Dep. Date	Nr. days	Distance	Codend + inner net	Introduction of	Reference
1980	Barents Sea	R/V M.Sars	18. May	25	3nm	42mm	Rubber bobbins	Tavares & Øynes (1980)
1981	Barents Sea	R/V M.Sars	12. May	33	3nm	42mm	Waco combi. doors, 1500kg	Teigsmark & Øynes (1981)
1982	Barents Sea	R/V M.Sars	19. May	22	3nm	42mm		Teigsmark & Øynes (1982)
1982	Svalbard	R/V M.Sars	12. July	21	3nm	42mm		Teigsmark & Øynes (1983a)
1983	Barents Sea	R/V M.Sars	25. April	31	3nm	42mm		Teigsmark & Øynes (1983b)
1983	Svalbard	R/V M.Sars	16. July	14	3nm	42mm		
1984	Barents Sea	R/V M.Sars	29. April	21	3nm	42mm		Hylen, Tveranger & Øynes (1984)
1984	Svalbard	R/V M.Sars	21. July	28	3nm	42mm		
1985	Barents Sea	R/V M.Sars	01. May	21	3nm	42mm + 4m 20mm		Tveranger & Øynes (1985)
1985	Svalbard	R/V M.Sars	19. July	24	3nm	42mm + 4m 20mm		
1986	Barents Sea	R/V M.Sars	23. April	26	3nm	42mm + 4m 10mm	Rockhopper gear	Hylen & Øynes (1986)
1986	Svalbard	R/V M.Sars	16. July	29	3nm	42mm + 4m 10mm		
1987	Barents Sea	R/V M.Sars	15. April	28	3nm	42mm + 4m 10mm		Hylen, Jacobsen & Øynes (1987)
1987	Svalbard	R/V M.Sars	25. July	25	3nm	42mm + 4m 10mm		
1988	Barents Sea	R/V M.Sars	23. April	28	3nm	42mm + 4m 10mm		Hylen & Øynes (1988)
1988	Svalbard	R/V M.Sars	19. July	33	3nm	42mm + 4m 10mm		
1989	Barents Sea	R/V M.Sars	17. April	32	3nm	42mm + 4m 10mm		Hylen, Sunnanå, Øynes (1989)
1989	Svalbard	R/V M.Sars	14. July	30	3nm	42mm + 4m 10mm		
1990	Barents Sea	R/V M.Sars	23. April	31	3nm, 1.5nm	42mm + 4m 10mm		Hylen & Ågotnes (1990)
1990	Svalbard	R/V M.Sars	19. July	15	1.5nm	42mm + 4m 10mm		

Year	Area	Vessel	Dep. Date	Nr. days	Distance	Codend + inner nett	Introduction of	Reference
1991	Barents Sea	R/V M.Sars	29. April	55	1.5nm	42mm + 4m 10mm		Berenbolm et al. (1992)
1991	Svalbard	M/T Anny Kræmer	05. August	42	1.5nm	42mm + 4m 10mm	"Steinshamn" doors	
							V-10, 2050kg	
1992	Barents Sea	M/T Gargia	02. May	29	1nm	42mm + 4m 10mm		Aschan et al. (1993)
1992	Svalbard	M/T Gargia	19. August	32	1.5nm	42mm + 4m 10mm	"Strapping"	
1993	Barents Sea	R/V Jan Mayen	22. April	20	1nm	42mm + 4m 10mm	Floats	Aschan et al. (1994)
1993	Svalbard	R/V Jan Mayen	29. May	21	1nm	42mm + 4m 10mm	"Steinshamn" doors	
1993	Svalbard	R/V Jan Mayen	30. August	10	1nm	42mm + 4m 10mm	W-9, 2050kg	
						and + 15m 20mm		
1994	Barents Sea	R/V Jan Mayen	25. April	22	1nm	42 mm + 15m 20 mm		Aschan et al. (1995)
1994	Svalbard	R/V Jan Mayen	23. May	21	1nm	42 mm + 15m 20 mm		
1995	Barents Sea	R/V Jan Mayen	18. April	20	1nm	42 mm + 15m 20 mm	Bag attached to	Aschan et al. (1996)
1995	Svalbard	R/V Jan Mayen	30. May	23	1nm	42 mm + 15m 20 mm	the under belly	
1996	Barents Sea	R/V Jan Mayen	15. April	20	1nm	42 mm + 15m 20 mm		Aschan & Berenboim (1997)
1996	Svalbard	R/V Jan Mayen	28. May	22	1nm	42 mm + 15m 20 mm		
1997	Barents Sea	R/V Jan Mayen	19. April	22	1nm	42 mm + 15m 20 mm		Anon. (1997)
1997	Svalbard	R/V Jan Mayen	26. July	16	1nm	42 mm + 15m 20 mm		

Table 3. Indices of shrimp biomass from Norwegian surveys in the years 1982-1997 by main areas.

Main area	A East Finnmark	B Tiddly Bank	C - Thor Iversen Bank	D - Bear Island Trench	E Hopen	F Bear Island	G Storfjord Trench	H Spitsbergen	Total	Sum. A,B,C, E
Strata	1 - 4	6 - 7	10 - 12	5, 8, 9, 13	14 - 18, 24	19 - 22/ 31 - 40	41 - 50	51 - 70		
Year										
1982	35	34	44	53	66	56	17	22	327	179
1983	40	57	61	53	112	52	21	33	429	270
1984	40	51	64	60	141	66	20	29	471	296
1985	23	17	27	18	96	31	17	17	246	163
1986	10	7	13	25	57	34	10	10	166	87
1987	29	13	18	23	31	10	9	13	146	91
1988	26	18	18	36	32	24	13	14	181	94
1989	41	17	13	17	33	53	22	20	216	104
1990	31	13	25	42	58	43	27	23	262	127
1991	22	28	22	54	120	44	21	10	321	192
1992	18	22	33	37	62	38	14	15	239	135
1993	17	19	32	29	85	20	12	19	233	153
1994	19	8	13	15	52	33	9	12	161	92
1995	10	10	11	17	83	33	16	13	193	114
1996	21	8	26	26	88	30	21	22	242	143
1997	24	29	20	36	93	41	12	16	271	166
+% 96/95	110	-20	143	55	6	-9	31	69	26	26
+% 97/96	14	263	-23	38	6	37	-43	-27	12	16

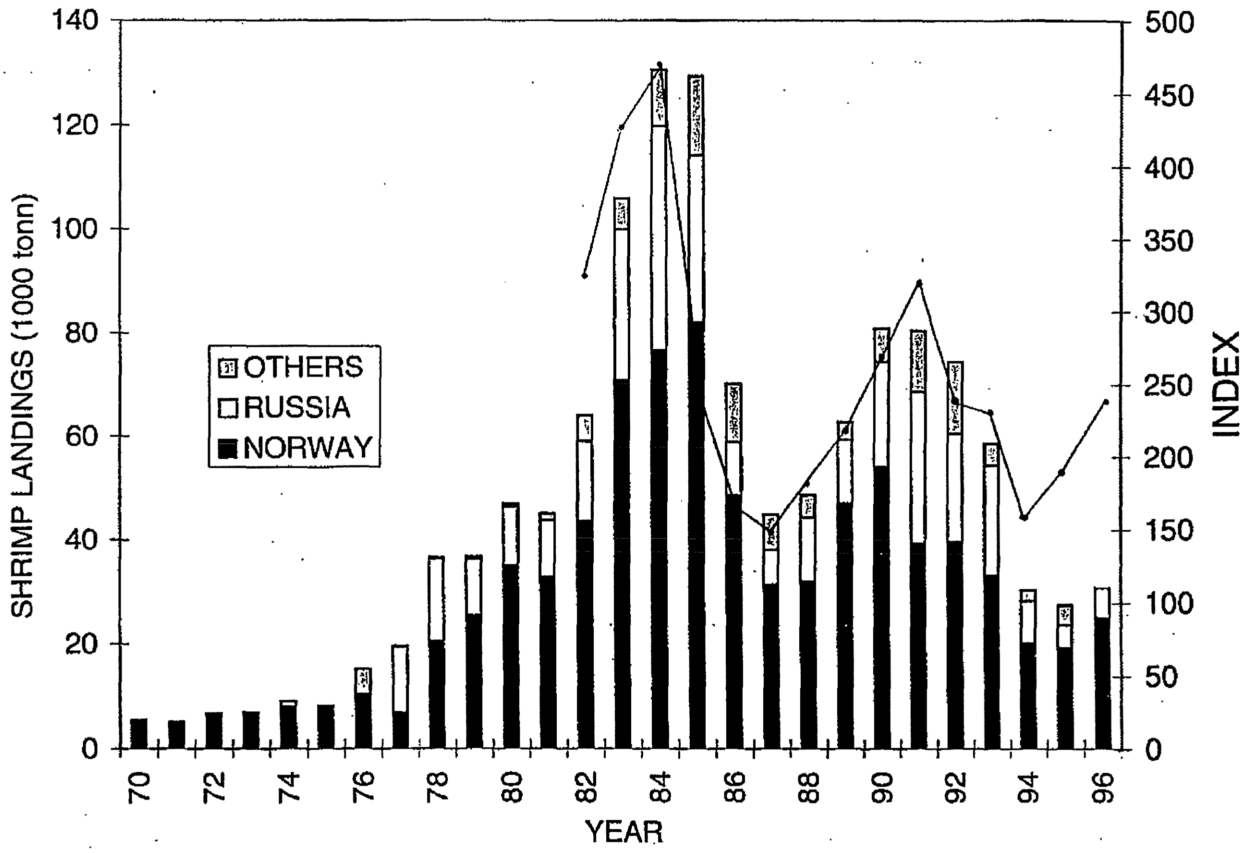


Figure 1. Shrimp landings in the Northeast Atlantic including ICES areas I, II a and II b and index of total shrimp biomass for the Barents Sea and the Svalbard area 1982-1996.

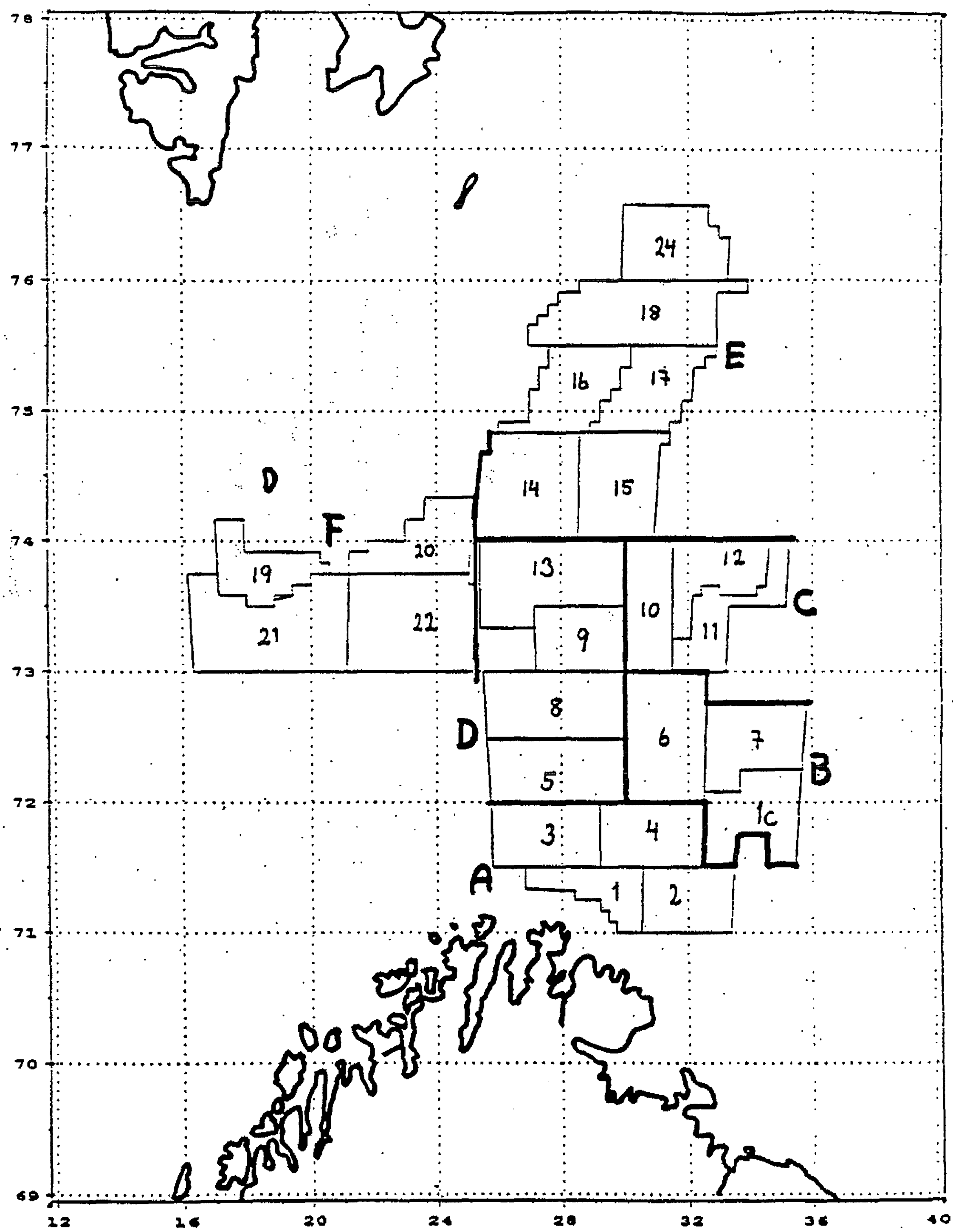


Figure 2. Sampling strata used for the shrimp surveys in the Barents Sea. Strata are combined to larger areas reflecting fishing grounds marked with letters A to F. East Finnmark (A), Tidly Bank (B), Thor Iversen Bank (C), Hopen (E) and Bear Island (F).

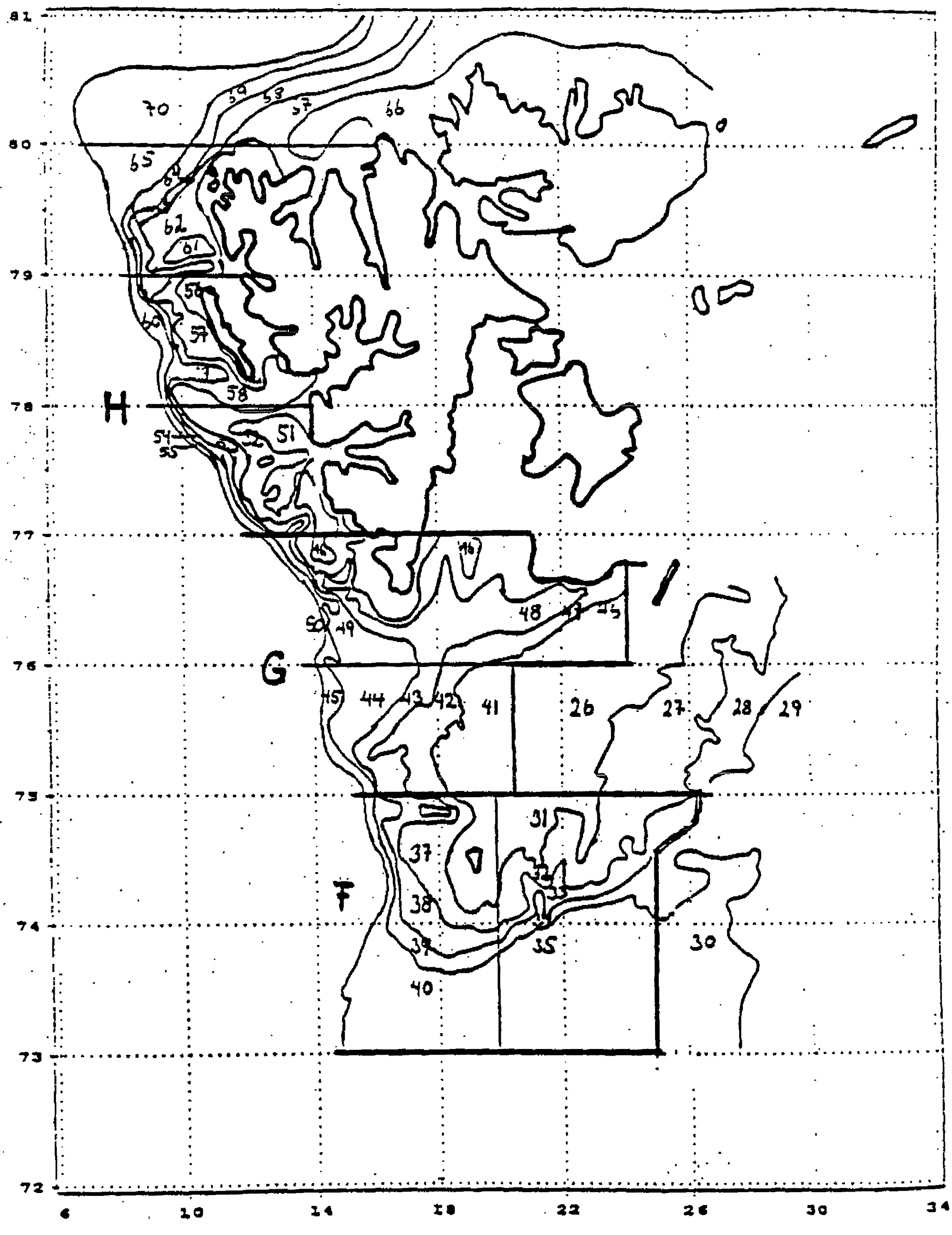


Figure 3. Sampling strata used for the shrimp surveys in the Svalbard area. Strata are combined into larger fishing grounds, Bear Island (F), Storfjord Trench (G) and Spitsbergen (H).

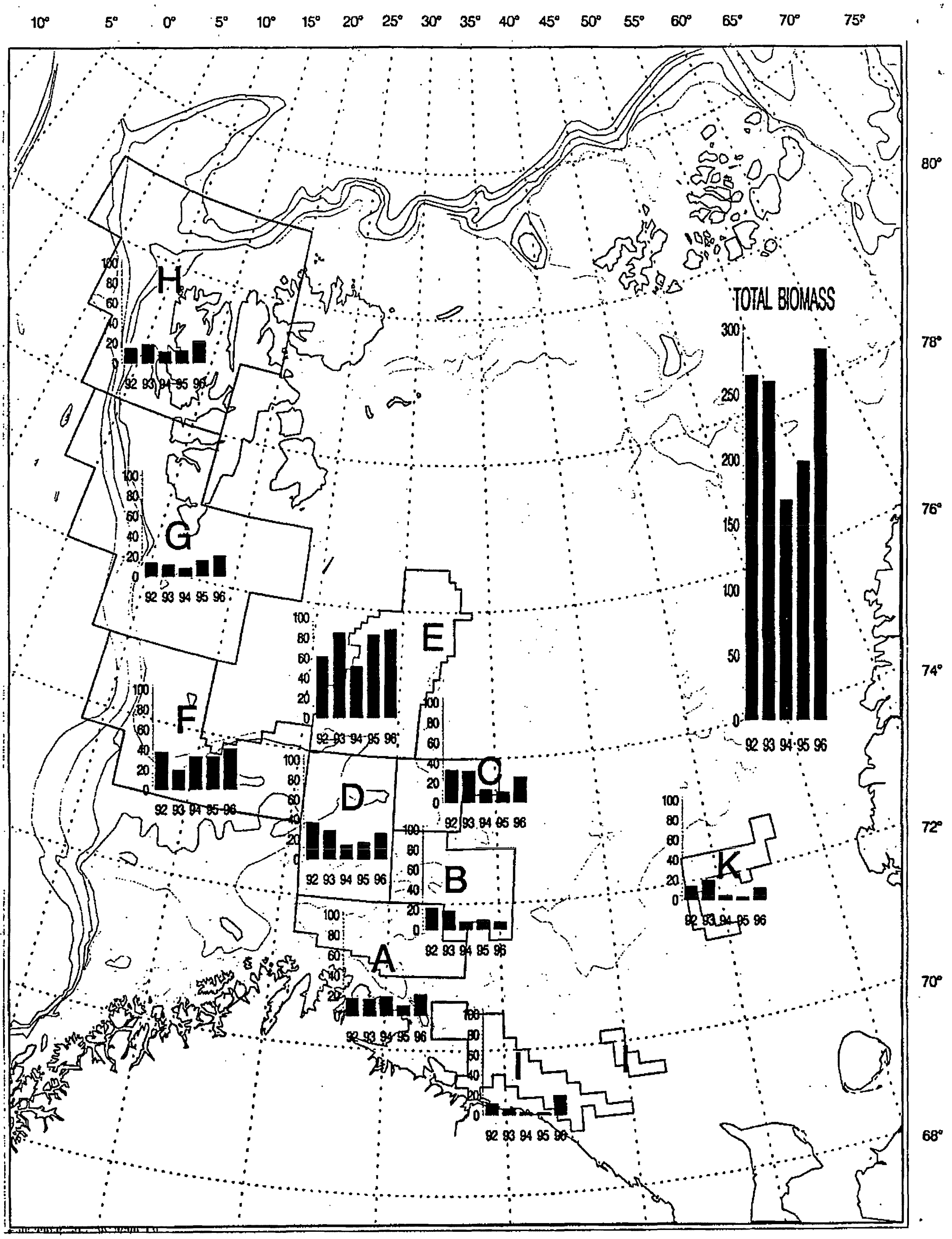


Figure 4. Biomass index 1992 -19976 in the main areas and for the whole area. Data on areas the Kola coast (I) and the Goose Bank (K) are based on Russian surveys (Aschan *et al.* 1996). East Finnmark (A), Tiddly Bank (B), Thor Iversen Bank (C), Hopen (E), Bear Island (F), Storfjord Trench (G) and Spitsbergen (H).

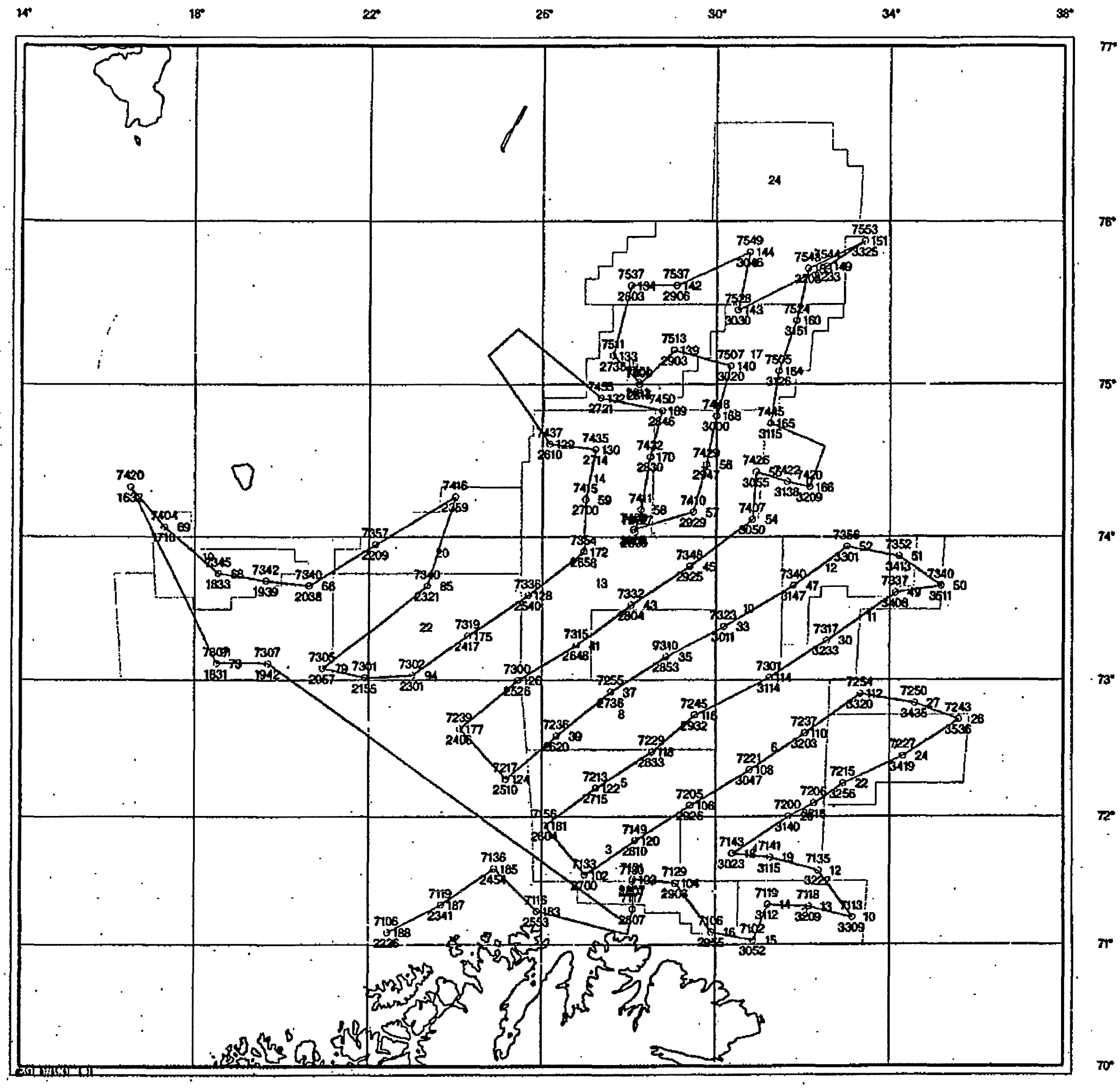


Figure 5. Sailing track and sampled stations of the shrimp survey in the Barents Sea, 19.04. - 9.05. 1997.

Fiskeriforskning Tromsø
F/F «Jan Mayen» Campelen 1800#
Panels

Date	
Survey	
Controlled by	

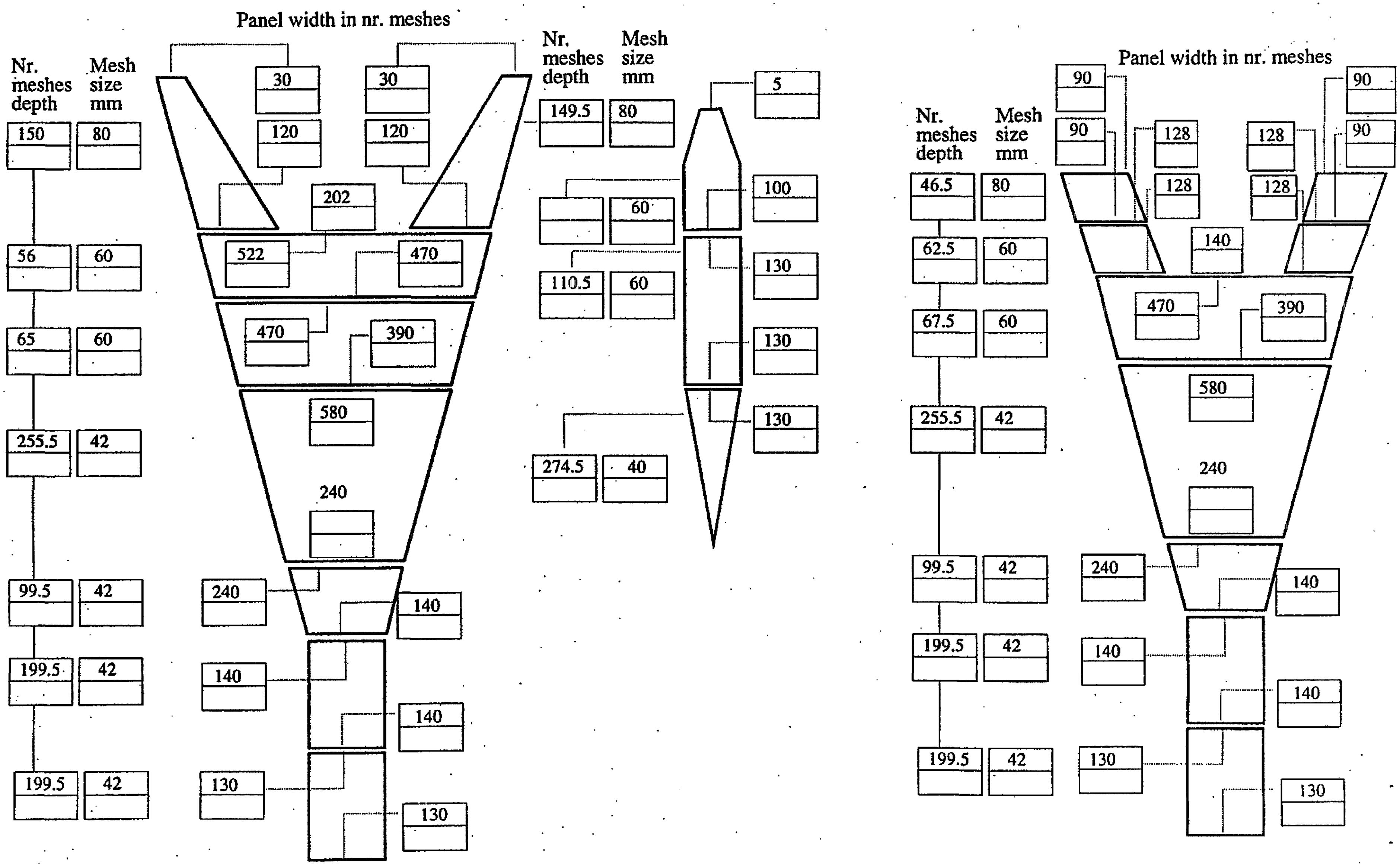


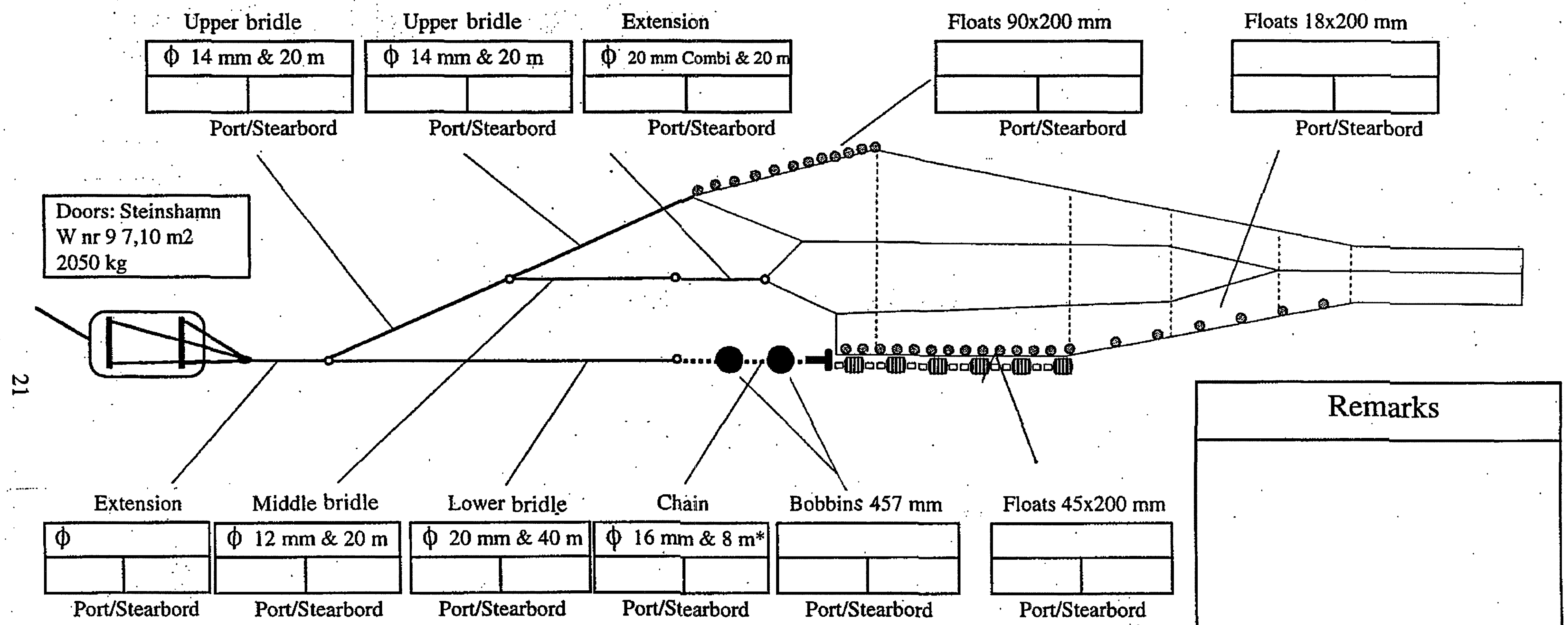
Figure 6. Control scheme for the panels in the Campelen 1800 shrimp trawl used as the standard trawl in the surveys.

Fiskeriforskning Tromsø

F/F «Jan Mayen» Campelen 1800#

Rigging

Date	
Survey	
Controlled by	



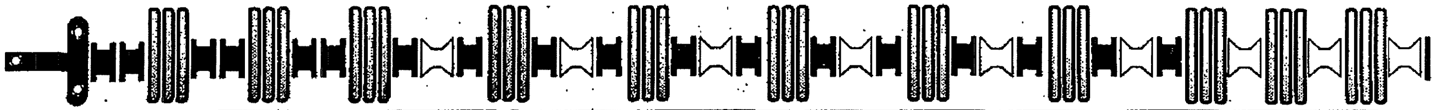
Remarks

Figure 7. Control scheme for rigging of the Campelen 1800 shrimp trawl used as standard trawl in the surveys.

Date	
Survey	
Controlled by	

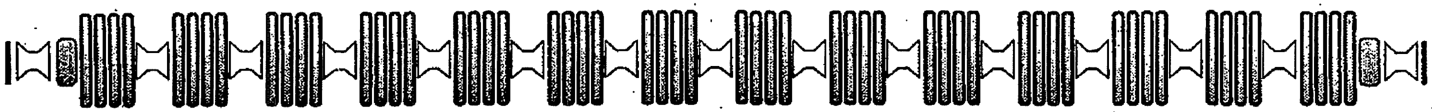
Fiskeriforskning Tromsø
F/F «Jan Mayen» Campelen 1800#
Rigging of rockhopper gear.

Port & stearbord section

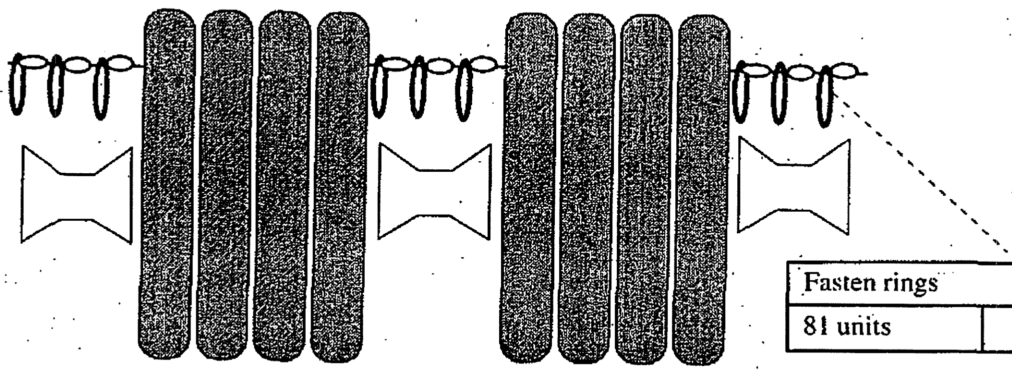


	14'' Rubberdisc		8'' Steel part		7,5'' Rubberpart		Stopper	
Port section	11x3=33 units		9 units		18 units		1 unit	
Stearbord section	11x3=33 units		9 units		18 units		2 units	

Mid section



14'' Rubberdisc		8'' Steel part		Rubberpart		Stopper	
14x4=56 units		15 units		2 units		2 units	



Fasten rings	
81 units	

Components	Weight per units (kg)	Total number	Total weight
14'' Rubberdisc	5	122	610
Steel part	6	33	198
Rubberpart	1	2	2
Rubberpart	1,5	36	54
Stopper	0,5	4	2,0
Centerchain 17mm	5,5 kg/m	19 m	104,5
Chain 7 mm	1,1 kg/m	19 m	20,9
Fasten rings		81	
SUM (≈)			991

Figure 8. Control scheme for rigging of Rockhopper gear.

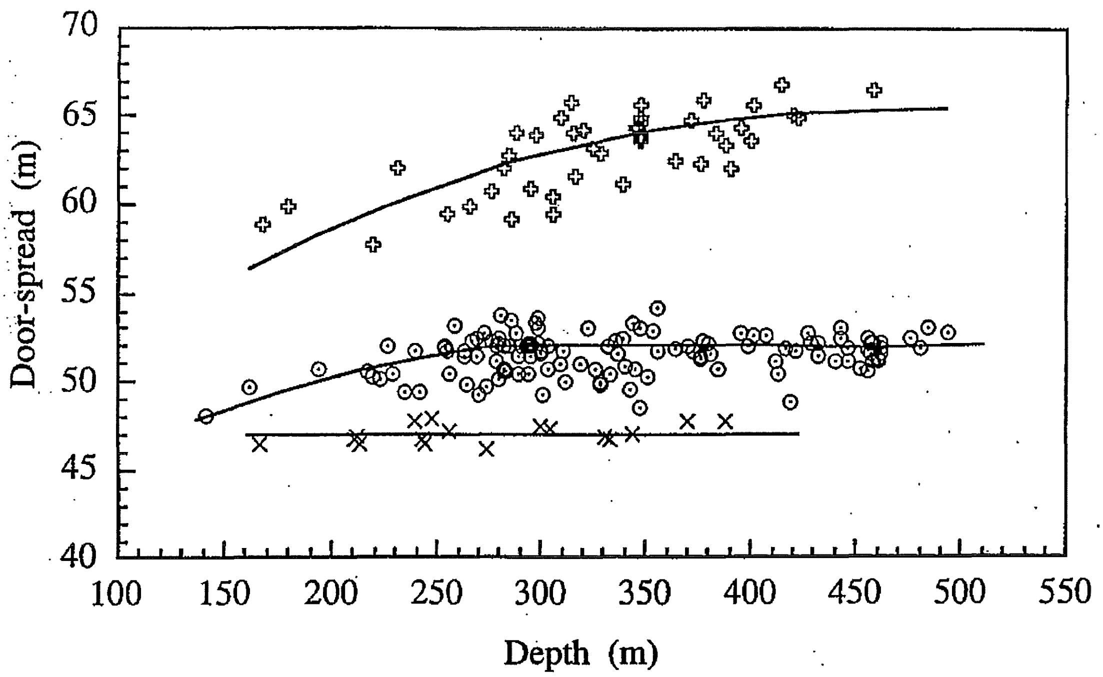


Figure 9. Door-spread against depth. With "Steinshamn" doors V-10 (two attachments) with "strapping" (⊙) and without "strapping" (✣) and W-9 (four attachments) with "'strapping'" (x). Results from shrimp cruises in 1992 and 1993 (Kristjansson 1994).

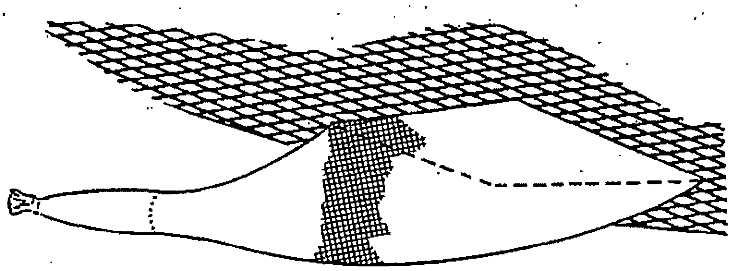


Figure 10. A fine meshed (8 mm) nylon bag with a 1 m² opening is attached under the lower trawl belly one m in front of the junction to the cod end.

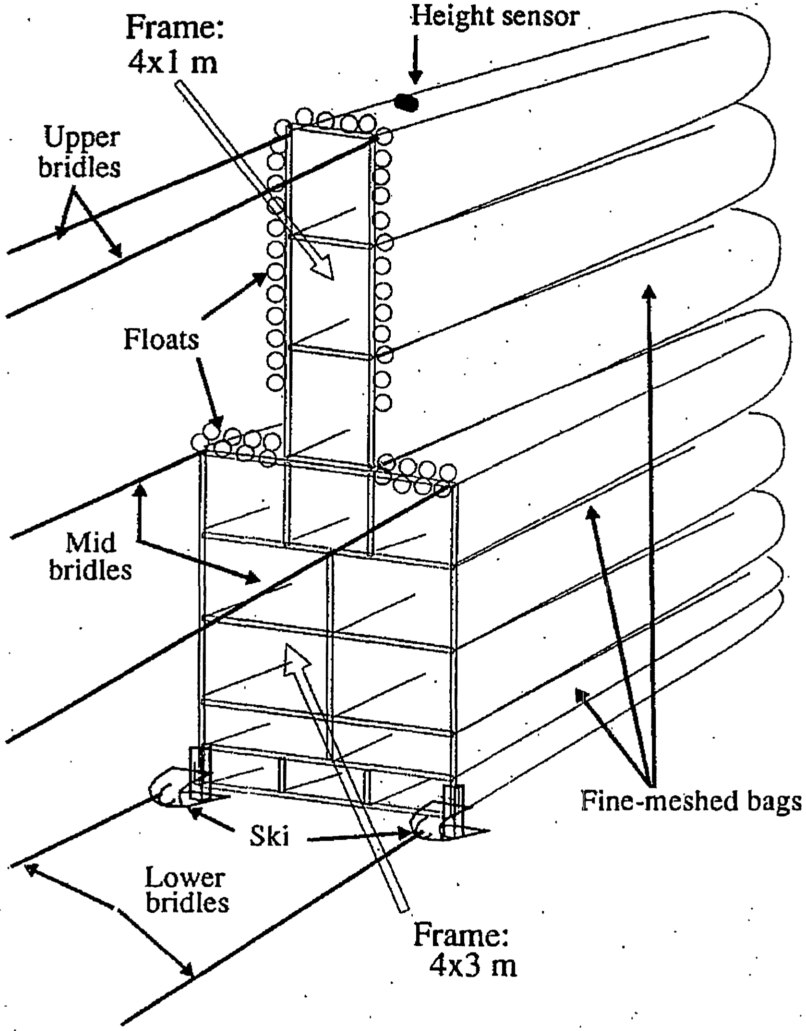


Figure11. Construction and experimental layout of the rigid shrimp-sampler. The figure shows the full 8 m tall version used in Lyngen, northern Norway, in March 1991. Earlier experiments during 1990 in Lyngen and in Spitsbergen lacked the upper, 4 × 1 m frame.

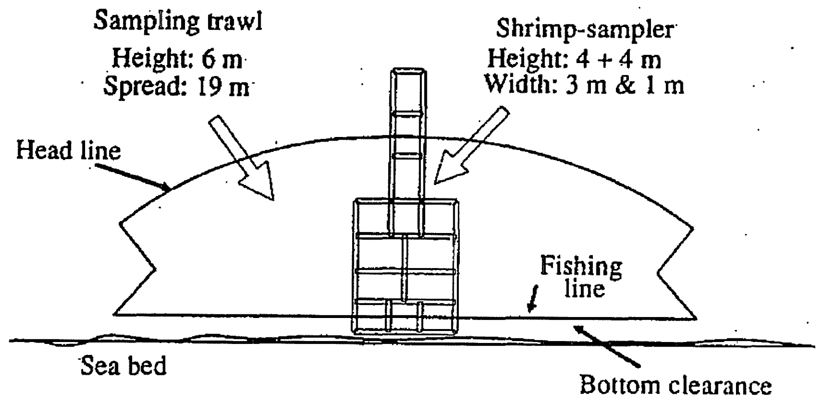


Figure12. Sketch (front view) showing the difference in geometry and sampling area between the standard sampling trawl and the rigid shrimp-sampler.

From Larsen *et al.* (1993)