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Occurrence, transport and retention mechanisms of Norway lobster (*Nephrops norvegicus*) larvae in the Skagerrak and the Kattegat

by

V. Øresland

By-catches in purse-seining with light for sprat and herring on the Swedish west coast 1997/98

by

F. Arrhenius, K. Frohlund, H. Hallbäck, P. Jakobsson and J. Modin

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Preface

"Meddelande från Havsfiskelaboratoriet, Lysekil" was first published in 1962. For many years the journal was edited as single reports in either Swedish or English. The latest edition, No 327, was published in 1995. We now have the pleasure to introduce you to a new edition and a new lay-out of "Meddelande från Havsfiskelaboratoriet, Lysekil". Our intension is to publish the journal twice a year with two or more papers in each edition. The language will be English and the papers will be refereed.

The Institute of Marine Research (Havsfiskelaboratoriet) in Lysekil, situated on the west coast of Sweden, is a department of the National Board of Fisheries.

I hope you will enjoy reading this new edition of "Meddelande från Havfiskelaboratoriet, Lysekil".

Lysekil, October, 1998

Jan Thulin
Editor

Occurrence, transport and retention mechanisms of Norway lobster (*Nephrops norvegicus*) larvae in the Skagerrak and the Kattegat

*(Förekomst, transport och retentionsmekanismer hos havskräftlarver (*Nephrops norvegicus*) i Skagerrak och Kattegat)*

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Abstract

This pilot study is the first attempt to examine the possibility of limitations in the transport of pelagic larval *Nephrops norvegicus* in the Skagerrak and the Kattegat, which might support stock separation of *N. norvegicus.* In addition, this study formulates hypotheses about larval development, and transport and retention mechanisms in the region, to be tested in future studies. Larvae of *N. norvegicus* were collected at 72 stations in the Skagerrak and the Kattegat in June and July 1996 using a modified Rectangular Midwater Trawl.

In this study, I hypothesize that the recruitment to bentic stages is affected by a larval anticlockwise transport pattern within the central and eastern Skagerrak. The low abundance of larvae (at zoea stage I) north of Denmark in June indicated limited or no transport of larvae from western Skagerrak at that time, and that the larval period started around May-June. I suggest that a possible transport of larvae from western Skagerrak will be highly variable in magnitude, and in its temporal and geographical distribution.

One hypothesis to account for the high abundance of larvae in the central part of the northern Kattegat in July is a retention mechanism in this area. I further hypothesize that larval production and survival, and transport and retention mechanisms in the Kattegat may affect recruitment along the Swedish Skagerrak coast. If correct, this would imply that the fishery (and mortality due to for example oxygen limitation) in the Kattegat may affect the fishery along the whole Swedish west coast. Knowledge of transport and retention mechanisms affecting larvae of *N. norvegicus* may be applicable

also for the pelagic eggs and larvae of commercial fish species. The larval abundance, distribution, and development of *N. norvegicus* should be studied in the Skagerrak and the Kattegat throughout the larval period in an effort to test these hypotheses.

Key words: Nephrops norvegicus, larvae, Skagerrak, Kattegat, distribution, zooplankton

Introduction

The economically important fishery for Norway lobster, *Nephrops norvegicus*, occurs in a number of geographically separate areas in the North Atlantic (Chapman 1980). Therefore, an ICES Working Group assesses the *N. norvegicus* stocks separately in the different areas. A crucial question in this assessment work is to what degree the population dynamics of one *N. norvegicus* stock can be regarded as independent from other stocks. At present, all *N. norvegicus* in the Skagerrak and the Kattegat are regarded as belonging to one single stock. Tagging experiments show that *N. norvegicus* does not undertake extensive migrations (Chapman 1980). Therefore, the most likely mechanism controlling the extent of stock independence is larval transport. There is a scope for larvae transport over long distances since the planktonic period is approximately 6-7 weeks long (see Nichols et al. 1987).

The recruitment of larvae to an area can be affected by retention of larvae produced within the area and/or by transport of larvae from other areas. In both cases, the interaction between biological and hydrographical processes may result in a larval recruitment that is variable on a time scale from days to years. Relatively few studies have been devoted to studying the temporal development and distribution of the planktonic larvae, the hydrographical processes involved, and the effect on stock independence and recruitment variability (Jorgensen 1925, Nichols et al. 1987, White et al. 1988, Hill 1990).

This pilot study is the first attempt to examine the extent of limitations in the larval transport of *N. norvegicus* in the Skagerrak and the Kattegat, which could support stock separation of *N. norvegicus*. In addition, this study intends to help formulate hypotheses about the temporal larval development, and larval retention and transport mechanisms in the region, to be tested in future more comprehensive larval studies of *N. norvegicus*.

Hypothesis

Figure 1 shows the main *N. norvegicus* fishing areas in the Skagerrak and the Kattegat and the water masses affecting the region. Larvae of different geographical origin may be transported into these fishing areas. It is assumed here that larvae occur mainly in the upper 50 m of the water column. However, larvae have been reported to occur at greater depths (Phillips and Sastry 1980). The Jutland Coastal Water and the Southern North Sea Water could possibly bring larvae from the southern North Sea. The Central North Sea Water could, perhaps, bring larvae from the central and northern North Sea. The Skagerrak Experiment in May - June 1990 (Danielssen et al. 1991, Danielssen et al. 1997) showed that the Norwegian Coastal Water could turn southwards (as indicated in Fig. 1) across the central Skagerrak (blocking the Jutland Coastal Water from moving further into the Skagerrak). Therefore, I hypothesize that larvae off the Norwegian coast could be transported across the central Skagerrak and towards the northern Kattegat and the Swedish coastal waters, together with larvae produced off the northern Danish coast.

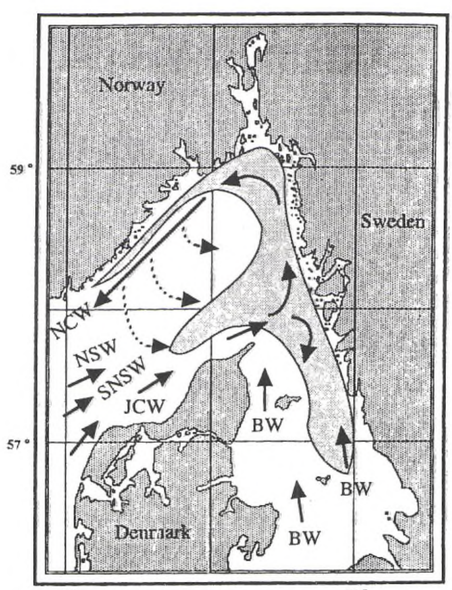

***Figure. 1.** Main fishing grounds (shaded area) of Nephrops norvegicus in the Skagerrak and the Kattegat (M. Ulmestrand pers. comm.) and schematic water mass movement (no deep water included, redrawn from (Dybern et al. 1994)). JCW=Jutland Coastal Water, SNSW=Southern North Sea Water, CNSW=Central North Sea Water, NCW=Norwegian Coastal Water, BW=Baltic Water*

Figure 2 shows the tracks of some of the ARGOS buoys deployed at 10 m depth during the Skagerrak Experiment in May - June 1990 (from Danielssen et al. 1991). Track no. 1 illustrates a typical Northern Jutland Current transport towards the Swedish coast. Track no. 2 illustrates water coming into the central Skagerrak but, on that occasion, not reaching the Swedish coast. The water mass movements in this region are variable in strength and extension, and periodically there will be no transport at all towards the Kattegat and Swedish coastal waters. From the above, I hypothesize that, if present, transport of larvae from western Skagerrak will be highly variable in magnitude, and in its temporal and geographical distribution. Transport of larvae can be limited by different retention mechanisms. Track no. 3 in the northern Kattegat was over 2 weeks long and indicates retention of water within an important fishery area. How typical this circulation pattern is for that area is not known in detail (B. I. Dybern pers. comm., see also Svansson 1984). However, I hypothesize that if such a circulation pattern occur at least temporarily during the summer it may affect retention of larvae within the northern Kattegat. Furthermore, the variability of such retention may also affect the transport of larvae from the Kattegat towards the Swedish Skagerrak coast.

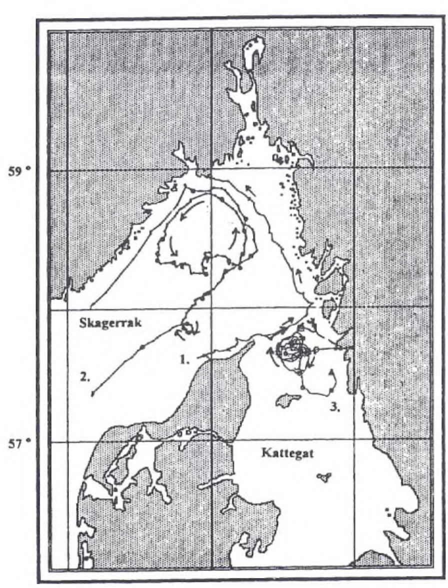

Figure 2. Tracks from three ARGOS buoys deployed at 10 m depth during the Skagerrak Experiment in May - June 1990 (from Danielssen, 1991).

The irregular shape of the Swedish Skagerrak coast, with its islands and fjords, coupled with hydrographical and meteorological factors could affect water movement and retention of larvae. Fig. 1 indicates that water flowing northwards along the Swedish coast may turn north-west towards the Norwegian Skagerrak coast. Therefore, I hypothesize that larvae transported to the Swedish coast, or produced locally, can be retained along the coastline but also transported to Norwegian waters. Together, these hypotheses can, if not disproved, explain larval anticlockwise transport pattern within the central and eastern Skagerrak.

Materials and methods

Larvae of *N. norvegicus* were collected during two cruises (stations according to figures 3 and 4) between 17-20 June (R/V Argos) and between 22-31 July 1996 (R/V Ancylus) using a modified Rectangular Midwater Trawl (RMT) (Clarke 1969). The first cruise started in June since females are known to start spawning around that time in the Kattegat and the Skagerrak (M. Ulmestrand pers. comm.). The RMT had no opening /closing mechanism. The opening area to inflowing water was 4 m^2 and total RMT length was 8 m. Mesh size was 500 μm. A knotless net (mesh size 1 cm) was mounted in the opening so scyphomedusae would glide off the net and not be caught inside the RMT. A calibrated General Oceanics Inc. flowmeter was mounted behind the knotless net, halfway between the centre of the net opening and the frame.

All hauls were made double oblique from the surface to near the bottom (usually within 0-10 m from the bottom) and back to the surface. When the bottom depth exceeded 50 m the RMT was taken down to a standard depth of approximately 50 m. Haul depth was given by a Scan Mar depth recorder (June cruise) or through wire length and angle estimation (July cruise). Sampling speed (RMT through water) was approximately 2-3 knots. Sampling time varied between 2 and 21 minutes. The samples were taken during both day and night time in June and during day time in July. The distance between the stations was 5 nautical miles except for the July stations off the Swedish Skagerrak coast (Fig. 4).

Zooplankton samples were preserved in 5 % formaldehyde in seawater. All zooplankton samples were sorted for *N. norvegicus* larvae at stage I, II and III (Nichols et al. 1987) using a stereomicroscope. Large samples were subdivided to 1/2-1/8 using a splitting box (Motoda 1959). The preserved larvae appeared to be in good condition except for frequently broken spines. The abundance of larvae at each sampling station was expressed as number per m^2 (calculated as mean number per $1m^3$ multiplied by maximum sampling depth in the oblique haul).

Results

Figure 3 shows that, during June, *N. norvegicus* was found (in low abundance) only at one station in the single south-north transect. The stations between Skagen and Sweden had somewhat higher abundance while some of the stations to the north and south in that area had no larvae at all. In the northern west-east transect there were only two stations close to the Swedish coast that had larvae. All *N. norvegicus* found in June were at stage I.

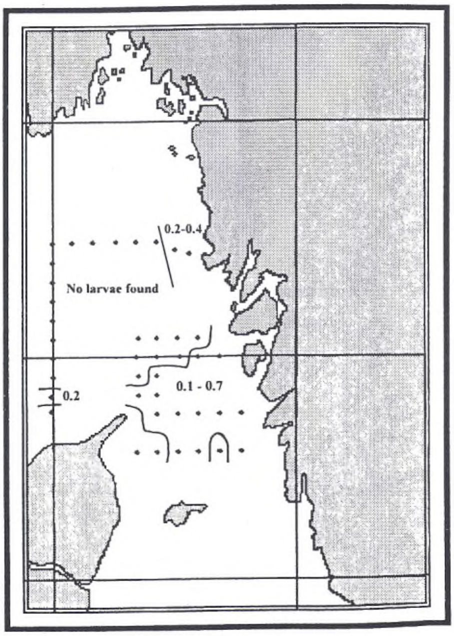

Figure 3. *Sampling stations attended 17-20 June 1996, and numbers of Nephrops norvegicus larvae (all at stage I) per m².*

Figure 4 shows that 4 weeks later, in July, the abundance of *N. norvegicus* had increased considerably in the northern Kattegat as well as in Swedish coastal waters. Larvae were found at all stations. The abundance was highest at three stations off the Swedish Skagerrak coast and in the central part of the grid in northern Kattegat. The stage distribution for the larvae caught during July was; 73 % at stage 1, 23 % at stage II, and 4 % at stage III.

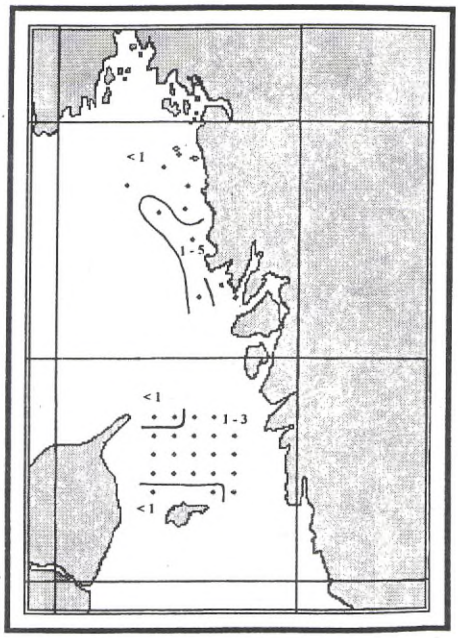

Figure 4. *Sampling stations attended 22-31 July 1996, and number of Nephrops norvegicus larvae (stage I, II, and III together) per m*^{2}.

Discussion

N. norvegicus was found only at one station in the single south-north transect during June. This indicates that there could only be a limited transport of larvae from western Skagerrak at the time of sampling. However, this may be due to a temporary reduction of water masses coming in from the west. Another reason may be that abundance was low in general. The occurrence of larvae at only the two stations closest to the Swedish coast in the northern west-east transect indicate that there was no direct transport from the western Skagerrak into that area. Therefore, those larvae were probably produced in the Swedish coastal waters and/or transported from the Kattegat. In July, the higher occurrence of larvae close to Skagen in Denmark indicates that transport from western Skagerrak can not be excluded at that time.

In July the abundance increased to levels similar to what has been found in larval studies in the Irish Sea (Nichols et al. 1987). The abundance was higher in the central part of the northern Kattegat (as also indicated in June). That could be due to a retention mechanism that concentrated the larvae. Other reasons could be that the production and/or survival of larvae could have been higher in the central area. It is at this stage impossible to evaluate the relative importance of these reasons for variability in abundance. Anyway, a better coverage of the area throughout the larval period would show the permanency of this distribution and abundance pattern.

It is difficult to interpret the few abundance data from the stations off the Swedish Skagerrak coast in July. The high abundance supports the hypotheses of retention along the coastline and transport from the Kattegat and other parts of the Skagerrak, as well as local production of larvae. The lower abundance at the most northern stations could, at least partly, be due to water movement away from the coast towards the Norwegian coast. The possibility of such a movement in that area was indicated by the ARGOS buoy track no. 1 in Fig. 2.

Lindquist (1970) reported how the anticlockwise current system in the Skagerrak affected the distribution of fish eggs and larvae in May and June 1963. His results (see Fig. 11a.) indicate a transport of the eggs of sprat (*Sprattus sprattus*) by the Jutland Coastal Water towards the Swedish coast, and then into the northern Kattegat, and also northwards along the Swedish coast. Therefore, knowledge of the transport and retention mechanism affecting *N. norvegicus* may partly be valid also for the eggs and larvae of commercial fish species. See also Munk et al. (1995) for occurrence of cod larvae in May 1992 in this area.

Hatching seems to occur between March and July in the Irish Sea, and the development time for zoea at stage I is reported to be 15 days (summarized in Nichols et al. 1987). The low larval abundance in this study and the fact that all larvae were at stage I between 17-20 June suggest that the larval production in 1996 started at a low level in May or early June. However, small scale hatching events earlier can not be excluded. Jorgensen (1925) reported that larvae at stage I were found between May and August off the Northumberland coast. It may be hypothesized that the larvae at stage I occur until September in the Skagerrak and the Kattegat since adult females carrying old eggs can be found at least until September (M. Ulmestrand pers. comm.).

Conclusions and suggestions

In this study I suggest a larval anticlockwise transport pattern within the central and eastern Skagerrak, with the possibility of a transport of larvae from the North Sea. However, I found no conclusive evidence of a transport of larvae from the western Skagerrak to the eastern Skagerrak in June. The larval period had just started at that time and abundance was still low. Therefore, I suggest that the larval abundance and development should be studied throughout the larval period in the area north and west of Skagen, in order to find supporting evidence for such a transport.

The high abundance in the central part of the northern Kattegat may partly be due to an open water retention mechanism. Therefore, I suggest that larval production and survival, and retention and transport mechanisms in the Kattegat may affect recruitment along the Swedish west coast. That hypothesis also implies that the fishery (and mortality due to for example oxygen limitation, see (Hallbäck and Ulmestrand 1990) in the Kattegat may affect recruitment (and the fishery) along the Swedish west coast. I suggest that the larval abundance and development should be studied from the northern Kattegat to the northern part of the Swedish west coast throughout the larval period, in order to find supporting evidence for this hypothesis.

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Sammanfattning

Denna pilotstudie är det första försöket att undersöka möjliga begränsningar i larvtransport av havskräfta, *Nephrops norvegicus* , i Skagerrak och Kattegat, som skulle kunna stödja beståndsseparation av *N. norvegicus*. Dessutom formulerar denna studie hypoteser angående larvernas utveckling, samt transport och retentionsmekanismer i regionen, som skall kunna testas inom framtida studier. Larver av *N. norvegicus* insamlades vid 72 stationer i Skagerrak och Kattegat under juni och juli 1996 med hjälp av en modifierad "Rectangular Midwater Trawl".

I denna studie föreslår jag hypotesen att rekryteringen till bottenlevande stadier av *N. norvegicus* påverkas av ett moturs transportmönster hos larver inom centrala och östra Skagerrak. Den låga förekomsten av larver (i zoea stadium I) norr om Danmark under juni indikerar att en begränsad eller ingen transport förekom från västra Skagerrak vid denna tidpunkt, och att larvperioden startade runt maj - juni. Jag föreslår att en möjlig transport av larver från västra Skagerrak är mycket variabel i styrka, samt i tid och rum.

Den höga förekomsten av larver i den centrala delen av norra Kattegat under juli stödjer hypotesen om en retentionsmekanism i detta område. Jag föreslår ytterligare att larvproduktion och överlevnad, samt transport och retentionsmekanismer i Kattegat kan påverka rekrytering längs med den svenska Skagerrak kusten. Om detta kan påvisas, så skulle fisket (och dödlighet beroende på exempelvis syrebegränsning) i Kattegat kunna påverka fisket längs hela svenska västkusten. Kunskap om transport och retentionsmekanismer som påverkar *N. norvegicus* kan vara tillämplig även för pelegiska ägg och larver av kommersiella fiskarter. Larvernas förekomst, utbredning, och utveckling bör studeras i Skagerrak och Kattegat under hela larvperioden i ett försök att undersöka dessa hypoteser.

By-catches in purse-seining with light for sprat and herring on the Swedish west coast 1997/98

(Bifångster i snörpvadsfiske med ljus efter skarpsill och sill på svenska västkusten 1997/98)

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Abstract

The purse-seine fishery with light for sprat *(Sprattus sprattus)* and herring *(Clupea harengus)* on the Swedish west coast was investigated during the 1997/98 fishing season (October-March). Catches of sprat were low, while catches of herring *(Clupea harengus)* were considered to be at a normal level. The catches of sprat were largest in the beginning of the season, while catches of herring dominated the rest of the season.

The fishing area from Kungsbacka to Strömstad was divided into three sub-areas: outside the skerries, inside the skerries and the fjords between Smögen and Marstrand. This season, 75% of the hauls were made outside the fjords. Catches of herring and sprat for human consumption constituted the largest proportion, over 80%, by weight. By-catches of other species were larger in the fjords than outside the skerries. On average, by-catches amounted to 2.3% of total catches, by weight.

Besides sprat and herring, 25 different species were caught, dominated by cod (*Gadus morhua*) (32% of total by-catch, by weight), whiting (*Merlangius merlangus)* and Norway pout (*Trisopterus esmarkii)* (together, 38% of total by-catch). On average, four different species per haul were taken as by-catches in the fjords and inside the skerries, while only 2.2 species per haul outside the skerries.

A weak correlation between light duration and size of by-catch was seen in the fjords.

The results of this investigation are similar to earlier ones in the same area in terms of catch composition and extent of the by-catches in purse-seining with light. The conclusion is that this fishery is of minor importance for other fish stocks at present.

Key words: by-catch, catch journals, purse-seine, light fishing, sprat, herring

Introduction

Purse-seining with light attraction is widely used in many parts of the world (Ben-Yami, 1988). The light makes it possible to catch pelagic fish that are scattered and difficult to catch during parts of the season. On the Swedish west coast, purse-seining with light has been used as a fishing method since the beginning of the 1960's (Lundin 1977). This fishery is mostly coastal and the target species is sprat (*Sprattus sprattus*), but herring (*Clupea harengus*) are also caught in large quantities. The fishery for sprat is mainly for human consumption to produce canned fish. The demand for sprat for anchovy style canning by the local industries has increased lately, especially for Christmas and Easter seasons in Sweden. The catches of sprat vary greatly between years, coinciding with large variations in year-class strength.

In Sweden, purse seining with light has been criticized in recent years by local authorities and by the public. It has been claimed that in this fishery, considerable amounts of young stages of many fish species are caught, including sprat and herring. It has also been argued that the lights interfere with the navigation of other boats and that the fishing boats sometimes obstruct other traffic activities.

During purse-seining with light, not only sprat and herring are attracted to the light source. Earlier investigations in Sweden and Norway show that many other species are attracted to the light and are caught together with the target species (Andréasson & Lindquist 1974; Øynes 1972; Tveite 1979). Øynes (1972) found 27 different species as by-catches in the purse-seining with light in Norwegian fjords, the most frequent ones being whiting (*Merlangius merlangus*), cod (*Gadus morhua*), pollack *(Pollachius pollachius)* and saithe *(Pollachius virens)*. However, none of these authors were of the opinion that the by-catches were of such quantity that they could affect the yield of other commercial fisheries.

During recent years, the methods have changed somewhat when it comes to the type and effect of the lights, as well as the gear used in this fishery. This means that the results of earlier investigations cannot be fully applied to the present situation.

The aim of this study was to investigate the catches of sprat and herring as well as the by-catches of other species of the fishery of purse-seining with light on the west coast of Sweden.

Methods

Background

The fishing unit consists of a seiner (the boat that is setting and hauling the seine) and a lamp boat. The total number of fishermen is 11. When a school of fish has been detected, normally by echo-sounder, the lights are turned on to attract and gather the fish. This operation may take several hours. There are no regulations on the light effect that a boat may have on board. The amount of light used on different occassions depends on the depth and the visibility of the water (Lundin 1977). Occassionally, the seine is set without using light, usually around larger herring schools.

The size and mesh of the purse-seine are selected to suit local conditions and the target species, i.e. sprat or herring. The ones used in the area investigated are up to 800 m in length and 80 m deep. A fine-meshed net is used because the fish are not entangled but are trapped by being surrounded by netting.

When the fish have gathered around the light, the seine is carefully set out around the school and then the lower wire is slowly hauled (Fig. 1). The lamp-boat then turns off the lights and crosses the floatline. The seiner is not able to navigate while the seine is set out and it may therefore drift with the wind or the current. The lamp-boat therefore "hooks up" with the seiner to keep it in position while the seine is being hauled. Finally, the seine hangs beside the boat like a large sack. The catch is taken onboard with the use of a large suction hose, placed inside the seine.

The composition of the catch determines the use of it. The canning industries accept "pure" catches of sprat or herring (no more than 10% admixture of other species) of sufficient sizes (for sprat a maximum of 55 individuals/kg, for herring it varies depending on the use). If this is not the case, the fish catch is transported to a fish-meal factory. However, this seldom happens since, if it is of insufficient quality, the catch is usually released before it is pumped onboard. Also, there are regulations on the size of the landings of certain protected species in the by-catches in the sprat fishery (FIFS 1993:30).

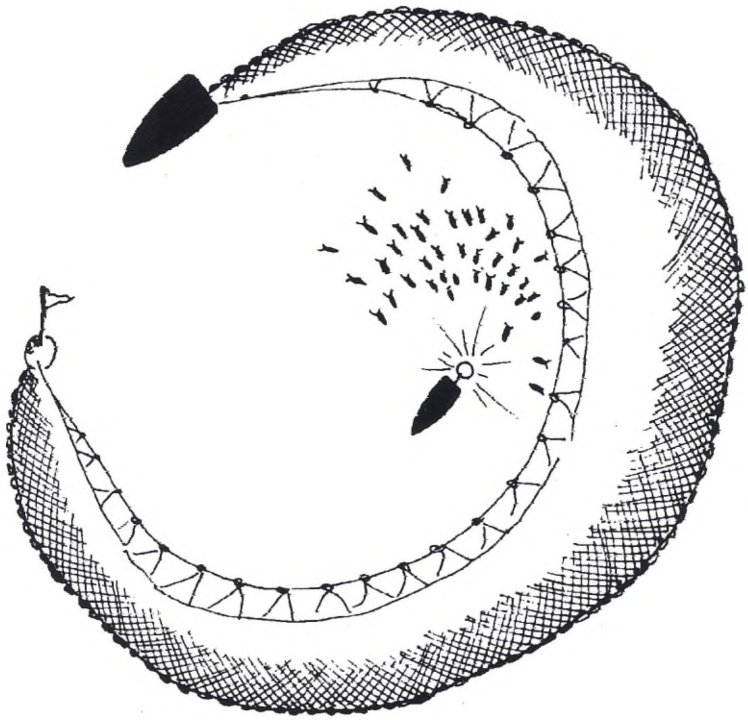

Figure 1. *Purse-seining with seiner and a lamp-boat. The seine is set around the fish, attracted and gathered around the lamp boat. (Redrawn from Ben-Yami, 1988).*

The fishing season 1997/98

The fishery

During the season of 1997/98 purse-seining with light took place between Kungsbacka in the south and Strömstad in the north (Fig. 2). The fishery followed the abundance and distribution of the target species sprat and herring into the coastal waters. There seems to be a migration of sprat from open sea into the coastal waters and the archipelago from October-December (Lindquist 1964).

The fishing season for purse-seining with light is between September and March. The landings of sprat and herring in the Skagerrak are restricted by a mixed clupeid fishing quota set annually by the EU-commission. The purse-seine fishery in Sweden is regulated by the Union of Swedish West Coast Fishermen (SVC). The boats leave the harbour at midnight between Sunday and Monday and must deliver their catches before 6 a.m. each day during the week. There is no fishing from Friday to Sunday.

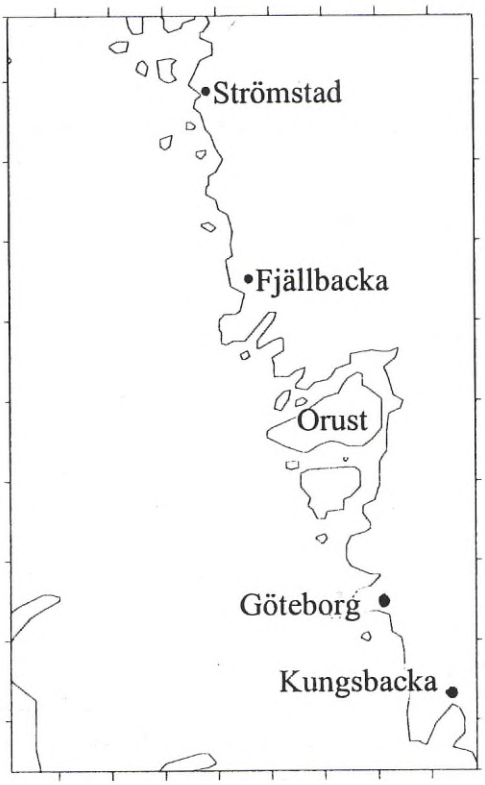

Figure 2. The fishing area of the purse-seining with light for sprat and herring on the Swedish west coast during the 1997/98 season.

Earlier investigations (Tveite 1979; Degerman & Sellius 1982) show that the catches and the extent of the sprat fishery vary between years and fishing locations during each fishing season. Therefore, it was impossible to predict where the different boats would be on different occasions. At times, all the boats may be in the same fjord, or they may be scattered along the coast. Because of this, the sampling scheme of this study could not be randomized.

Catch journal monitoring

In order to get a picture of the total catches during the season, the skipper of each seiner recieved a specially designed "catch journal" with forms to fill in for each haul. In these, data on time of day, date, location, depth, weather, light effect, light-time and catches (total catch, proportion of sprat, herring and industrial fish) were reported.

Sampling of the catches

The research vessel "Ancylus" was used for transportation between boats and as housing for the staff in this investigation. When the fishing boats left the harbour, radio contact was established with the fishing fleet to follow the fishery and allocate sampling effort.

The scientific personnel were transported to the seiner shortly before or just after the seine had been set. When the fish were sucked up by the hosepipe, ten evenly distributed samples were taken (≈10 l or ≈6 kg fish per sample). Since the catch is not homogenous, it was important to have samples evenly distributed in the catch. Normally, the samples were analysed directly on board.

Within each night of sampling, samples from up to four hauls could be collected. The overall aim was to sample all active boats during each week of sampling. Three geographical strata were used: samples were taken from hauls outside and inside the skerries, as well as in the fjords. The main emphasis was given to the two latter areas, since earlier information from fishermen indicated that fishing outside the skerries seldom give any by-catches.

The samples were divided into three categories; sprat, herring and other fish species (by-catch). Sprat and herring were counted and measured as total weight of the sample. The other species were identified to species and measured to total length to nearest cm below and wet weight was determined to nearest gram.

Results

The entire fishing season 1997/98

Catches reported to the SVC

Four fishing units participated in the purse-seining with light during the season 1997/98. The purse-seining season was opened on October 6, 1997. Due to bad weather (heavy winds), the first hauls were not made until October 15.

Herring were caught throughout the whole fishing season (October - March) but sprat were only reported between October and January.

The total catches of sprat from October -97 — March -98 amounted 871 metric tons. More than 90% of the catches were done by purse-seining with light, the rest with trawls and gill-nets (Fig. 3)

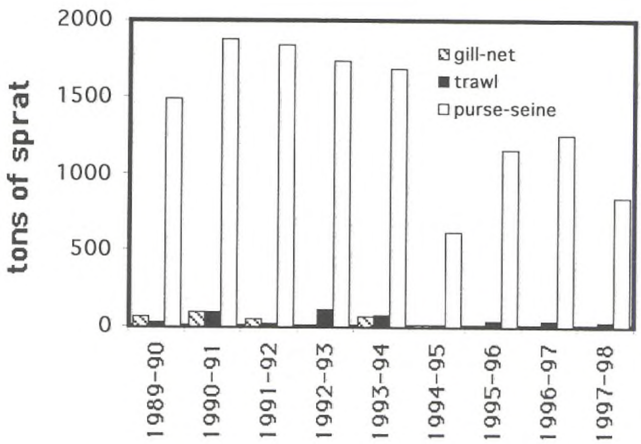

Figure 3. *Annual total catches in the sprat fishery during the seasons 1989/90 - 1997/98. (Data from: L. Larsson, SVC). The catches are divided into fishery with purse-seines using light, trawls and gill-nets.*

Catches reported in catch journals

The specially designed catch journals were used during the most intense fishing period (October - January) and all hauls (157) during this period were reported. The reported sprat catches showed a peak at the end of November (Fig. 4). However, during the entire season, the catches were dominated by herring intended for human consumption (≈ 2000 metric tons). The percentage of sprat decreased from more than 60% of total catch in October to 15-20% during the rest of the fishing season (Fig. 5). From the catch journals, a total of more than 600 metric tons of sprat for human consumption was reported. The amount of undersized herring and sprat was on average 5-15% of the total catch and amounted to about 230 metric tons. Other fish species constituted only a minor part of the total yield in weight (Fig. 5).

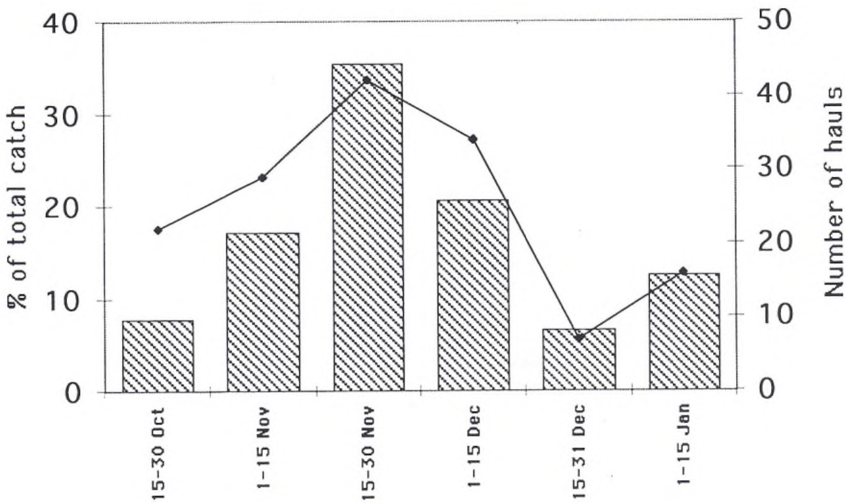

Figure 4. *Sprattus sprattus. The purse-seining with light catches divided into two-week intervals as percentage of entire catches during the period 15 October 1997 - 15 January 1998. Data were taken from the specially designed catch journals used in this investigation. The line represents the total number of hauls during each two-week interval.*

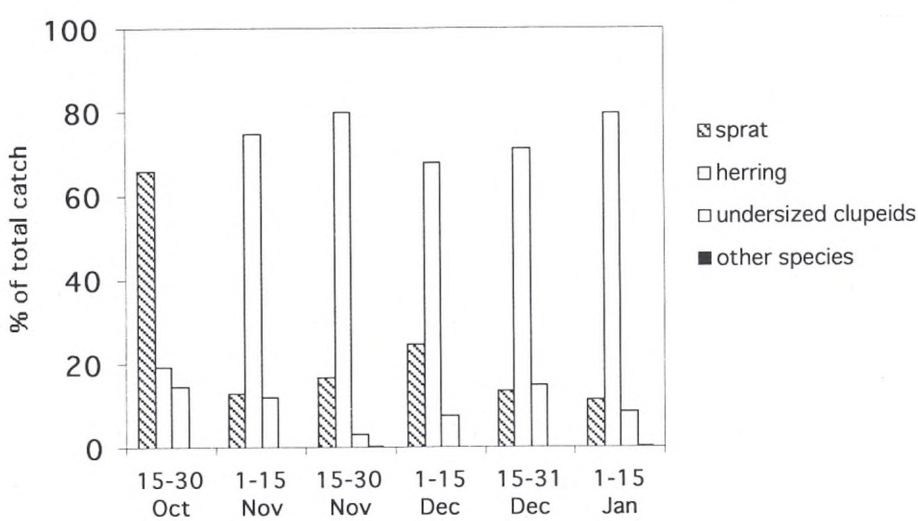

Figure 5. *Percentage of sprat and herring for human consumption, undersized sprat and herring and other fish species in relation to total catches during two-week periods from 15 October 1997 - 15 January 1998. Data were taken from the specially designed catch journals used in this investigation. The figure is based on 157 hauls.*

In order to get a spatial pattern of the fishing activity using purse-seining with light, the area was divided into three sub-areas; outside the skerries, inside the skerries and the fjords (Fig. 6).

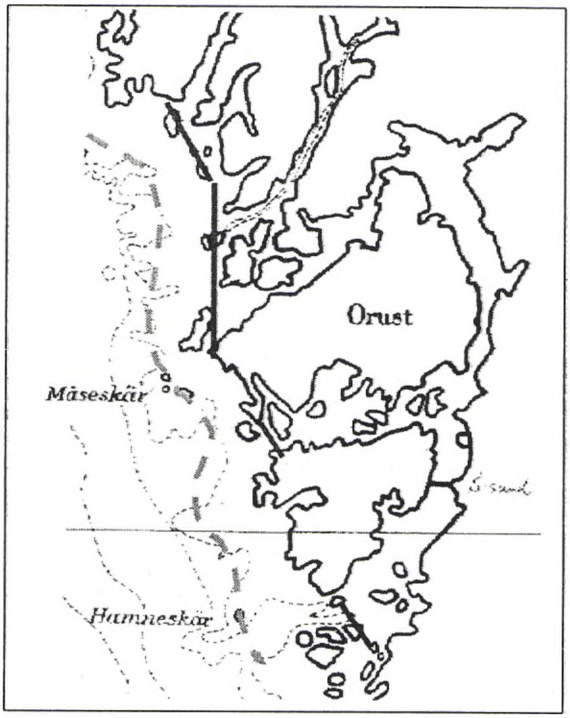

Figure 6. The classification of the area strata of purse-seining with light fishery of the Swedish west coast used in this investigation. Outside the skerries was defined as the area in line with outer islands with depths of 30 m or more and outwards (outside dashed line). Inside the skerries (area between dashed and continuous line) was the area inside outer islands but outside fjords. The fjord area (inside continuous line) was all water within fjords from Smögen to Marstrand (except the Koster Fjord and the Kungsbacka Fjord).

Classification by sub-areas of the 157 available catch journal records showed that 17% of all catches during the period of investigation (October - January), were made outside the skerries, 58% inside the skerries and the remaining 25% in the fjords (Fig. 7). A correction for non-reported catches and the full season is expected to result in an increased percentage of catches taken outside the skerries.

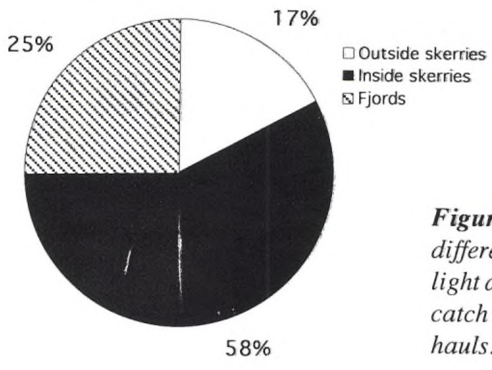

Figure 7. The distribution of catches in different sub-areas in the purse-seining with light during the season of 1997/98. Data from catch journals. The figure is based on 157 hauls.

Sampling in the fishery

Total catches

A total of 284 samples were collected from 29 hauls, 15 of these were taken in fjords, 10 inside the skerries and 4 outside the skerries (Table 1). Total weight of single catches varied considerably (between 3.2 - 68.2 metric tons). The average individual weight was between 22-25 g for all areas for sprat and 44-74 g for herring, with the lowest values inside the skerries (Table 2). The catches of herring was of variable size composition inside the skerries.

Light (above surface light) was used to attract fish in 26 out of these 29 hauls. The light time varied substantially between hauls, with the longest time period to attract fish was done inside the skerries. The average water depth at the different fishing grounds was 40 m outside the skerries and in the fjords and around 30 m inside the skerries (Table 3). The smallest catches were made in the fjords and towards the open waters (Table 3).

Herring dominated the catches in all three sub-areas and outside the skerries constituted >99% by weight of the total catches. The proportion of sprat was on average 30-40% in the fjords and inside the skerries (Fig. 8).

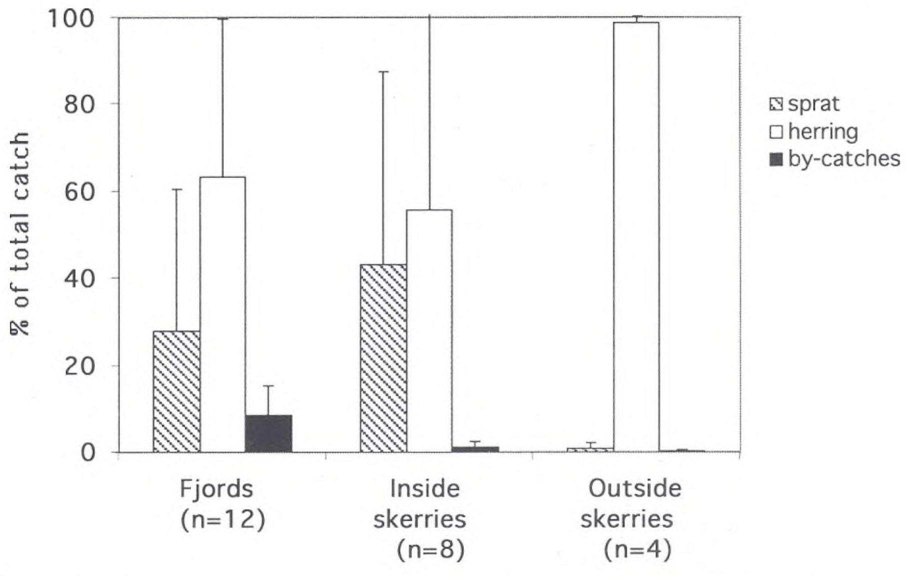

Figure 8. *Percentages, by weight, of sprat, herring and by-catches of total catches in each area in the purse-seining with light investigation in 1997/98. Standard deviation (±SD) on top of bars.*

Table 1. *Data of hauls used in the purse-seining with light investigation 1997/98. Sub-area (A being outside skerries, B inside skerries and Ç in the fjords), depth, light duration, time of day and total catches (kg) are presented for each haul, For each haul total number of samples, average weight (±SD) and number and percentage of the different categories (sprat, herring and other species, all including undersized individuals). Due to lack of time in field, data on number of individuals and/or weight of each fraction is missing for some samples, indicated by a dash. These are not included in Fig. 8.*

Haul no.	Area	Depth (m)	Light duration (h)	Day/ Night	Catch (kg)				Sampling results					
						no of samples	average weight (kg)	SD	weight (%)					
									sprat	herring	others	sprat	herring	others
1	B	25	2	N	5000	10	-	-	-	-	-	1531	547	11
2	B	50	?	N	10000	10	-	-	-	-	-	1692	105	69
3	C	30	6	N	3750	10	-	-	-	-	-	2173	830	98
4	B	32	3	N	10570	10	6.9	0.68	66.0	31.7	2.3	1769	740	27
5	B	20	5	N	4600	10	6.0	0.46	91.1	6.7	2.2	2371	151	8
6	B	25	3	N	12040	10	5.1	0.88	2.3	96.7	1.0	34	817	10
7	B	25	4	N	9140	10	5.5	0.46	85.2	14.8	0.0	2016	266	20
8	B	30	1	N	5000	10	4.9	0.50	95.7	3.5	0.9	2996	65	20
9	B	30	2	N	7700	10	5.1	0.74	3.7	94.7	1.6	113	1450	9
10	A	34	1	N	30000	10	6.2	0.67	0	100	0	0	805	0
11	A	32	1	N	20000	10	5.2	0.61	2.1	97.5	0.4	50	760	11
12	B	45	2	N	8000	10	8.1	1.04	1.5	98.3	0.2	146	1079	12
13	C	45	0	D	9000	10	5.8	0.93	0.4	99.3	0.2	13	930	0
14	A	35	0	N	12000	10	5.1	0.72	1.9	93.0	5.1	36	659	3
15	B	35	0	N	7600	10	5.3	0.59	0.4	88.3	11.3	9	730	5
16	C	55	2	N	68150	10	7.1	0.69	4.5	79.3	16.2	156	983	5
17	C	60	5	N	32000	10	8.7	0.96	1.1	83.8	15.2	31	1171	20
18	C	70	5	N	18200	10	6.7	0.63	0	88.7	11.3	0	912	57
19	C	70	6	N	13000	10	8.1	0.82	0.2	89.0	10.8	5	1167	108
20	C	72	4	N	8000	10	9.0	1.29	0.1	94.9	5.1	2	1420	58
21	C	25	3	N	31250	10	6.3	1.40	82.4	15.3	2.3	2859	132	17
22	C	30	4	N	18000	10	5.4	0.97	67.7	15.6	16.8	2361	117	20
23	C	40	4	N	30000	10	-	-	-	-	-	-	-	36
24	C	28	3	N	25500	10	5.4	1.02	62.1	37.9	0.0	-	-	3
25	C	30	3	N	10000	9	5.2	0.84	74.6	24.6	0.7	-	-	17
26	C	25	3	N	5000	5	6.2	0.86	18.4	64.5	17.0	-	-	23
27	A	70	2	N	16000	10	7.0	1.14	0	100	0	0	984	1
28	C	70	4	N	35000	10	5.6	1.08	0.0	99.8	0.2	2	865	16
29	C	26	2	N	3250	10	5.4	0.83	80.3	19.7	0.0	-	-	16

Table 2. *Individual average weight (in grams) of sprat and herring in the different sub-areas (±SD) in the 1997/98 purse-seine investigation.*

	Outside skerries		Inside skerries		Fjords	
	Weight	±SD	Weight	±SD	Weight	±SD
sprat	25.2	4.0	22.0	8.1	23.2	8.1
herring	72.6	4.6	44.3	20.8	74.1	6.8

Table 3. *Data on average light time, total catches and depth in the different sub-areas (±SD) of the hauls presented in Table 1.*

	Outside skerries		Inside skerries		Fjords	
	Average	±SD	Average	±SD	Average	±SD
Depth (m)	45.1	19.0	31.7	9.4	42.8	18.2
Lighttime (h)	2.1	1.9	3.9	1.2	2.8	1.0
Total catch (ton)	25.4	17.4	14.8	14.6	10.3	6.8

By-catches

Total catches of other species than sprat and herring were 8.6% by weight in the fjords, about 1% inside the skerries and less than 1% outside the skerries (Fig. 8). A total of 700 individuals (*i.e.* all except sprat and herring) were examined to species, length and weight (Table 1). Maximum by-catch in weight was recorder from a haul in the fjords in which 17% by weight of the total catch was made up of by-catches, inside the skerries the highest recorded by-catch was 11.3% and outside the skerries only 0.4% (Table 1).

On average four fish species (herring and sprat excluded) were caught per haul in the purse-seining with light in the fjords and inside the skerries, whilst outside the skerries, only 2.2 species per haul were caught (Fig. 9). In this investigation 25 different species were recorded as by-catches in the purse-seining with light. Of these, 16 different species were recorded in the fjords, 17 inside the skerries and only 6 outside the skerries (Table 4). In the fjords the most common species were cod *(Gadus morhua),* whiting *(Merlangius merlangus),* anchovy *(Engraulis encrasicolus),* Norway pout *(Trisopterus esmarkii),* saithe *(Pollachius virens),* mackerel *(Scomber scombrus)* and horse mackerel *(Trachurus trachurus).* Inside the skerries the most common species were cod, whiting, flounder *(Platichtys flesus)* and sardine *(Sardina pilchardus).* Among the few species caught outside the skerries, only whiting appeared in more than one haul. In general, cod, whiting and Norway pout were more common than other species, irrespective of area.

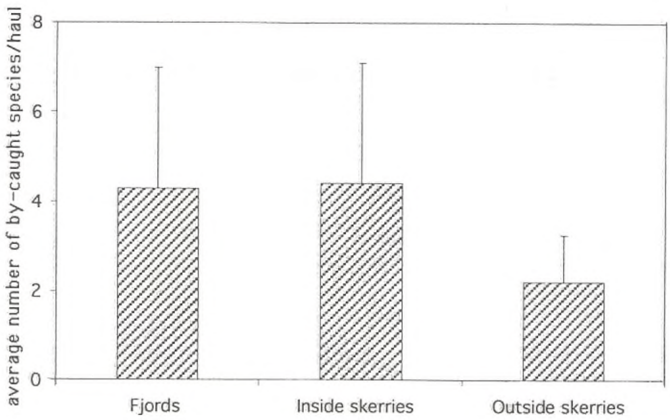

Figure 9. Average number of species caught (excluding herring and sprat) in the three sub-areas (Fig. 6), standard deviation (±SD) on top of bars.

Most of the by-caught fish were between 10 and 30 cm (Fig. 10). The largest variation in size (15-51 cm) was for cod in the fjords, but the length span from the two other sub-areas was much less (10-26 cm). In the fjords, more than 50% of the cod were ≥35 cm. It should be pointed out that large cods were also caught outside the skerries. However observed visually, they were not recorded in the sampling scheme, probably because they were so large and scarse. Among other species, average length did not vary substantially between sub-areas. However, it was noted that the lengths of whiting varied between 7 and 36 cm in the fjords and inside the skerries, but only between 10 and 22 cm in catches from outside the skerries. In the fjords, large individuals of saithe (18-37 cm) and mackerel (25-39 cm) were also recorded.

Table 4. *Abundance of different species in the purse-seining with light in 1997/98, divided into the three sub-areas (number of hauls in brackets). ***=Species present in more than 25% of hauls, **=species present in more than 10% but less than 25% of hauls, *= species present in less than 10% of hauls.*

		Fjords (15)	Inside skerries(10)	Outside skerries (4)
cod	*Gadus morhua*	***	***	**
whiting	*Merlangius merlangus*	***	***	***
anchovy	*Engraulis encrasicolus*	***	**	
Norway pout	*Trisopterus esmarkii*	***	*	**
saithe	*Pollachius virens*	***	**	
mackerel	*Scomber scombrus*	***	**	
horse mackerel	*Trachurus trachurus*	***	**	**
hagfish	*Myxine glutinosa*	**		
bullrout	*Myoxocephalus scorpius*	**		
eel	*Anguilla anguilla*	**		
ballan wrasse	*Labrus berggylta*	*	**	
pollack	*Pollachius pollachius*	*		
sea bass	*Dicentrarchus labrax*	*		
haddock	*Melanogrammus aeglefinus*	*		
long rough dab	*Hippoglossoides platessoides*	*		
dab	*Limanda limanda*	*	**	
flounder	*Platichtys flesus*		***	
hake	*Merluccius merluccius*		**	
red mullet	*Mullus surmuletus*		*	
plaice	*Pleuronectes platessa*		**	
sand goby	*Pomatoschistus minutus*		**	**
sardine	*Sardina pilchardus*		***	
dragonet	*Callionymus lyra*			**
sole	*Solea solea*		*	
black goby	*Gobius niger*		*	

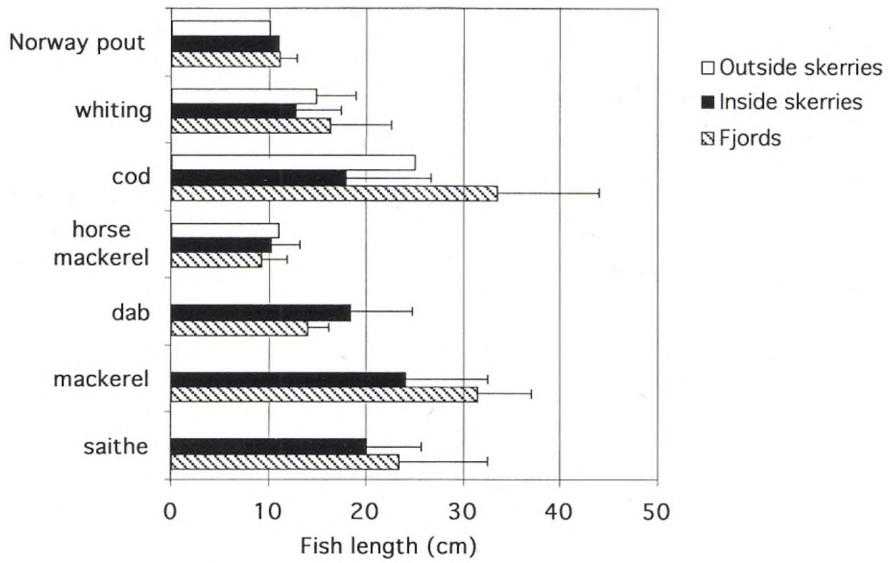

Figure 10. *Average length (standard deviation on top of bars) of the most common species found in the purse-seining with light of 1997/98 in three different sub-areas; fjords, inside and outside the skerries.*

The most abundant species, with reference to number of individuals, were Norway pout, whiting and cod in the fjords and whiting and dab *(Limanda limanda)* inside the skerries (Fig. 10a). Outside the skerries, only whiting was to some extent abundant (Fig. 11a). However, if the by-catches are expressed as weight per 1000 kg total catch, cod was the most dominating by-caught species in the fjords (>35 kg/metric ton) (Fig. 11b), whilst the portion of whiting, Norway pout, eel *(Anguilla anguilla)* and saithe varied between 5 and 15 kg per metric tons total catch. The catch composition inside and outside the skerries was similar.

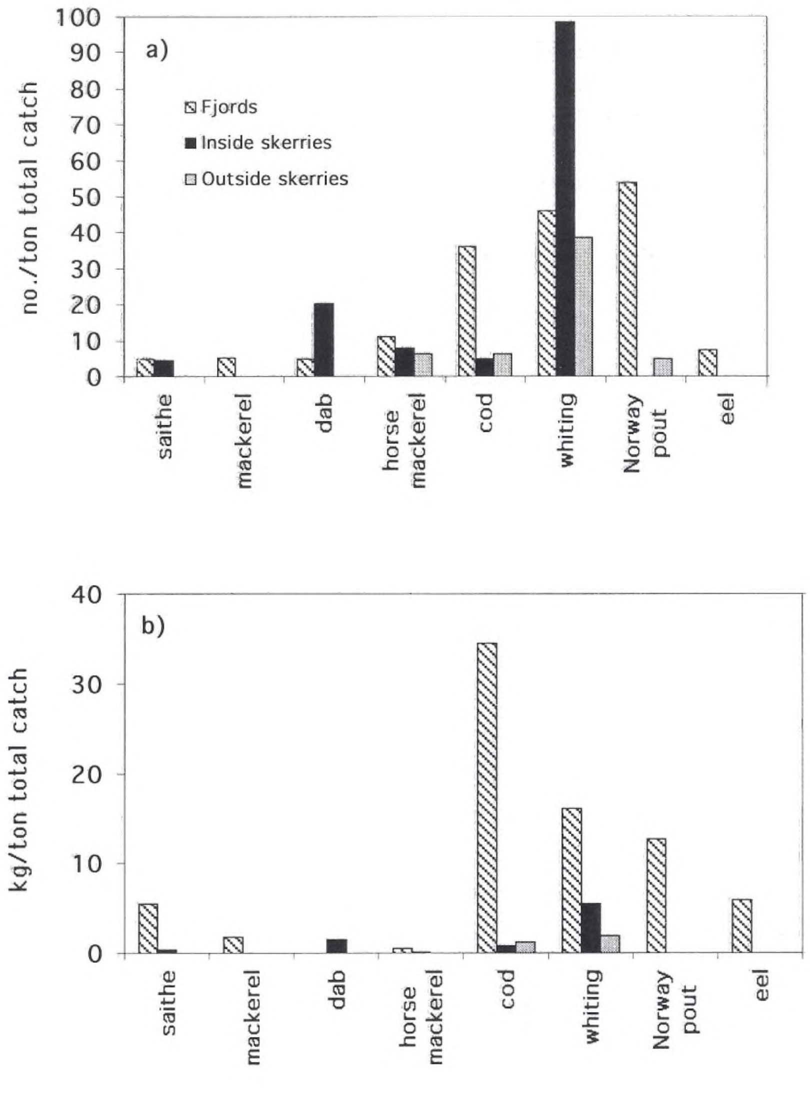

Figure 11a-b. *Average number (a) and weight (b) of the most common by-caught species per 1000 kg of total catch in the investigation of the purse-seining with light season of 1997/98.*

A comparison of total weight of by-caught species and total catch shows that about 2.3% (66.9 metric tons during the season 1997/98) was made up of by-caught species (average of all three sub-areas) (Table 5).

Cod made up about 32% by weight of the by-catches, whiting and Norway pout almost 38% in the fjords (Table 6). Inside and outside the skerries, whiting made up about 50% of the weight of the by-catches (Table 6).

Table 5. *Estimated weight of by-catches (metric tons) in three different sub-areas (estimations based on percentages reported in catch journals), total catch of all species in the whole fishery as well as average catch per haul and by-catch per haul in the investigation in the purse-seining with light during the season of 1997/98.*

		Skerries			
		Outside	Inside	Fjords	Sum
Distribution of hauls	%	17	58	25	100
By-catch/total catch	%	0.3	1.4	8.7	
Average weight/haul	ton	50.3	29.3	20.4	
Total catch (estimated)	ton	1458.7	849.7	590.4	2900
By-catch (estimated)	ton	4.3	11.5	51.1	66.9
Estimated by-catch as % of total catch					2.3

Table 6. *Percentages, by weight, of cod, whiting, Norway pout and other by-caught fish species of total by-catches in the investigation in 1997/98.*

	Skerries		
	Outside	Inside	Fjords
cod	31.5	10.1	32.5
whiting	50.8	52.4	20.3
Norway pout	0.0	1.2	17.4
other species	17.7	36.3	29.8
	100%	100%	100%

Factors that may affect by-catches

Light duration

The effects of light duration on the catch composition have often been discussed. In this investigation it seems that the proportion of by-catches varies greatly with light duration (Fig. 12a). However, there is a poor correlation between length of light time and the by-catch/total catch quota in the fjords.

Depth

There was no correlation between depth at fishing ground and proportion of by-catches in the fishery (Fig. 12b).

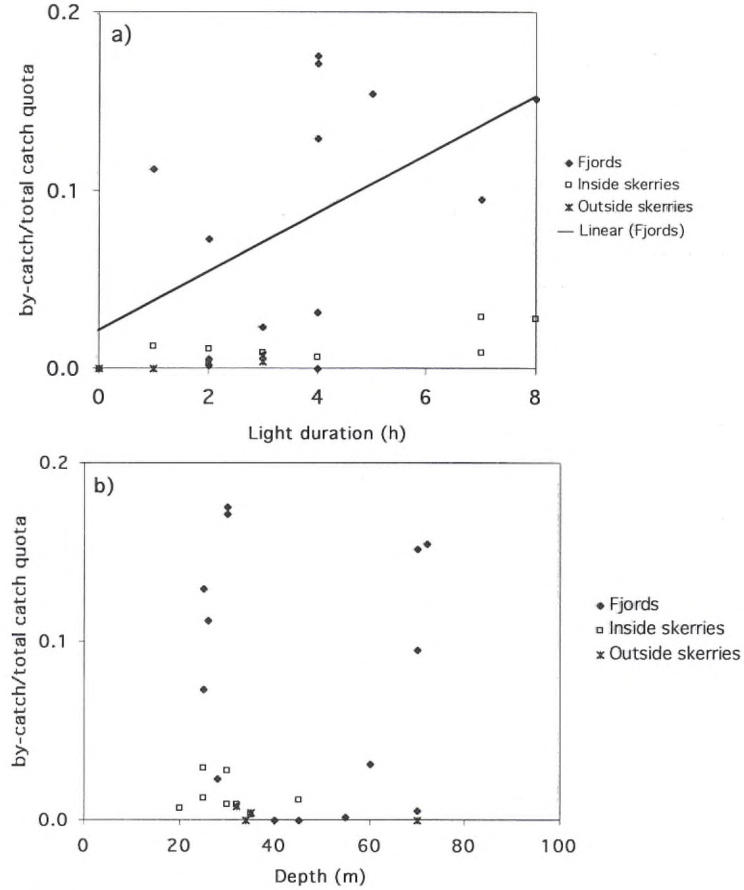

Figure 12a-b. *a) Proportion of by-catch of total catch plotted against light duration (regression line for fjords, y=0.0164+0.0218, R^2=0.27). b) Proportion of by-catch of total catch plotted against depth.*

Size of catch

There was no correlation between weight of by-catch and of total catch (Fig. 13).

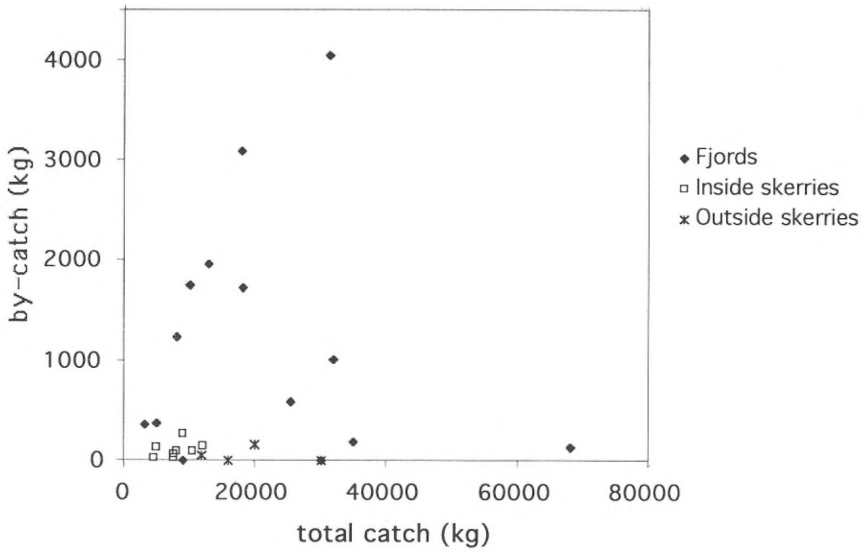

Figure 13. *Weight (in kg) of by-catches in the different sub-areas plotted against weight (in kg) of total catch.*

Discussion

During the purse-seining with light fishing in the season of 1997/98, the supply of sprat was poor along the entire west coast of Sweden. The total sprat catches were the lowest in a 15-year period (Fig. 14). The explanation for this is unclear. However in a near-by fjord in Norway, sprat appeared in relatively large quantities this season. These specimen were reported to be of poor quality, suggesting a low fat content, whilst the ones caught on the west coast of Sweden were of much better quality. Herring catch levels in the 1997/98 fishing season were normal, dominating overall catches - as has been recorded in the Swedish purse-seine fishery during recent years (pers. comm., L. Larsson, SVC). The catches in the fishery show great seasonal, annual and geographical variation, depending on the movement of the different schools of sprat and herring, the stocks being relatively short-lived and on great natural variation in recruitment and stock size. This variation makes the fishery for clupeids very unpredictable between years and within fishing seasons. In the 1997/98 fishing season the fishery started outside the skerries and moved inwards as the supply of clupeids increased and then moved back outside the skerries. Of the hauls reported in the catch journals, 75% were made outside the fjords. The fishing fleet followed the schools from the skerries into the fjords in the middle of the winter. Clupeids, especially sprat, seem to prefer warmer water in late autumn and winter and changing temperature conditions may explain the migration pattern of sprat (Lindquist 1978).

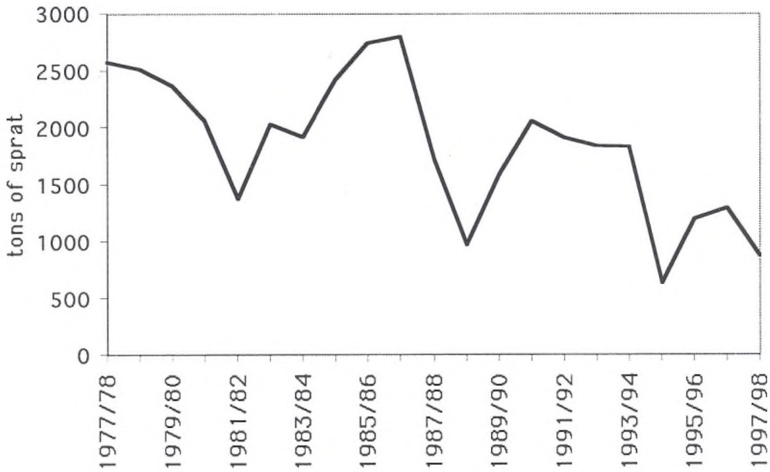

Figure 14. *Total seasonal catches in the Swedish west coast sprat fishery between 1977-1998 (Data from L. Larsson, SVC)*

The sprat and herring caught during the fishing season of 1997/98 did not vary much in size between the three areas, except for herring caught inside the skerries. This could indicate variations in age. We could not see any indications of more undersized fish towards the fjords.

When using light with a fishing method, not only sprat and herring are attracted. Total by-catches of species other than sprat and herring were largest in the fjords and smallest outside the skerries. The highest percentages of by-catches in single hauls were 17% in the fjords, 11.3% inside the skerries and 0.4% outside the skerries. An earlier investigation in this area by Andréasson & Lindquist (1974) showed by-catches of up to 15% of total weight in single hauls. However, in most of the hauls in this, and in earlier studies, the proportion of by-catches were considerably smaller (Table 1).

Estimated weight of by-catches in the entire fishery during the season of 1997/98 is about 2% of total weight. This was also seen in another investigation in the fjords from Marstrand to Uddevalla by Degerman and Sellius (1982); by-catches made up on average 2% of total weight.

In this investigation 25 different species were seen as by-catches. This is comparable to the investigation by Øynes (1972) who found 27 different species as by-catches in purse-seining with light in Norwegian fjords. In the study by Andréasson and Lindquist (1974) on the west coast of Sweden, only 17 species were caught. However, that study was mostly done outside the fjords, and thereby comparable to the results in this study. It should be noted, however, that on a per haul basis, the average number of by-caught species were only 4 in the fjords and inside the skerries and 2.2 outside the skerries.

Generally, the most common by-caught species, irrespective of sub-area, were cod, whiting and Norway pout, both by weight and by numbers. An earlier investigation in this area showed whiting, cod, pollack and saithe to be most abundant in by-catches (Andréasson & Lindquist 1974). In near-by fjords in Norway, whiting, blue whiting *(Micromesistius poutassou)*, cod and mackerel were the most common (Øynes 1972). In another smaller investigation on the west coast of Sweden, based on only two hauls in the 1988/89 season, cod and whiting were the most common by-caught species (pers. comm., M. Ulmestrand, Institute of Marine Research, Lysekil).

The results indicate a minor effect of light duration on the quantity of by-catches in the fjords. This effect was also documented in an earlier investigation by Andréasson & Lindquist (1974). Light is used to attract and gather the school, which may be rather large to start with, and it may therefore require quite some time. In the beginning of the 1960's, experiments were made with different light methods of attracting and gathering the fish at the Institute of Marine Research in Lysekil. From these experiments, it was reported (Lindquist 1963) that neither the effect of the light source, nor the physical size of the lamp play major rolls in the efficiency of attracting the fish, but the important thing is the contrast between light and dark. Hence the well known poor results when light fishing takes place during full moon. Also, if the light hits the sea floor or particles in the water, it is scattered and thereby blurred and the fish are frightened and take off. Best results are obtained when the water is clear, deep and dark (Lindquist 1963). Weaker light attracts and gathers large herring better than strong light, though.

The sampling in this study did not cover the entire fishing season or the entire fishing area. However, the samples seem to be representative, which is also indicated by the results of the catch journals, where no or very low by-catches were reported in the outer skerries and also after the sampling period.

The purse-seine fishery with light along the Swedish west coast is rather small but very important for the local canning industry. The proportion of by-catches are highest in the fjords, but the fishing pressure is smallest in this area compared to the other areas. It seems that the clupeids move into the fjords in the winter for favourable temperature.

The proportion of by-caught fish in the catches increases into the fjords. Many of these species use the coastal areas as nursery areas. The stock sizes of these species are not well known, especially inside the coastal areas. However, there are assessments of commercially important stocks from the Skagerrak and Kattegat area (pers.comm. P-O. Larsson, IMR, Lysekil). These figures are often uncertain and it is not known how large part of the stock that resides in the coastal areas of the westcoast of Sweden. In a rough calculation for the cod stock, the amount taken in this fishery seems to be minor part of the total stock (pers comm. P-O Larsson, IMR, Lysekil). Therefore, our main conclusion is that the by-catches in this fishery are of minor importance for the main fish stocks. If however, the purse-seining with light should increase in the area, especially inside the fjords, it is of vital importance that this fishery is further investigated.

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Sammanfattning

Under säsongen 1997/98 (oktober-mars) undersöktes snörpvadsfisket med ljus efter skarpsill *(Sprattus sprattus)* och sill *(Clupea harengus)* på svenska västkusten.

Under större delen av säsongen var skarpsillfisket mycket dåligt längs hela västkusten. Dock ansågs sillfisket vara av mera normal karaktär. För skarpsillens del var fångsterna störst tidigt på säsongen (oktober), medan sillfisket var mer intensivt resten av säsongen.

Fiskeområdet mellan Kungsbacka och Strömstad delades in i tre delområden; ytterskärgård, mellanskärgård samt fjordsystemet mellan Smögen och Marstrand. Denna säsong gjordes 75% av kasten utanför fjordarna. I snörpvadsfångsterna var den konsumbara delen av sill och skarpsill över 80%. Bifångster av andra arter var större i fjordarna än i ytterskärgården. I medeltal var bifångsterna viktmässigt ca 2,3% av totalfångsten.

Förutom sill och skarpsill förekom 25 olika arter i bifångsterna varav de vanligaste var torsk *(Gadus morhua)* (viktmässigt 32% av totala bifångster), vitling *(Merlangius merlangus)* och vitlinglyra *(Trisopterus esmarkii)* (tillsammans 38% av totala bifångster). I medeltal fångades 4 olika arter per kast som bifångst inne i fjordarna och i mellanskärgården, medan endast 2.2 arter per kast fångades i ytterskärgården.

Det fanns en svag korrelation mellan lystid och mängden bifångst inne i fjordarna.

Undersökningen visar liknande resultat vad gäller bifångsternas sammansättning och omfattning som tidigare lysfiskeundersökningar i området. Vår slutsats är att detta fiske för närvarande har ingen eller liten effekt på övriga fiskbestånd i området.

The institue's logo that can be seen on the title-page represents Bronze Age fishermen; from a rock-carving at Ödsmål, parish of Kville, Bohuslän, Sweden. From thousands of rock-carvings in western Sweden this is the only known scene showing fishing. Originally described by Åke Fredsjö, 1943: "En fiskescen på en bohuslänsk hällristning" - Göteborgs och Bohusläns Fornminnesförenings tidskrift 1943: 61-67. Later documentation by the same author in: "Hällristningar i Kville härad i Bohuslän. Kville socken. Del 1 och 2." - Studier i nordisk arkeologi 14/15, Göteborg 1981, 303 pp., Pl. 158 II. Published by Fornminnesföreningen i Göteborg.