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Forsmark site investigation

The coastal fish community in the Forsmark area SW Bothnian Sea

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October 2005

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Keywords: SW Bothnian Sea, Forsmark, Fish, Species composition, Biomass, AP PF 400-04-57.

Abstract

This report describes a compilation of data concerning occurrences and biomasses of different fish species in coastal areas at the Swedish east coast. The analysis has been performed by the Institute of Coastal Research at Swedish Board of Fisheries at the request of SKB. Data will be used in the system ecological model for the coastal area outside Forsmark which will be set up in connection to the site description.

Variation in CPUE and species composition was studied with multi-mesh gill-nets for six localities in the Baltic Sea offshore mid-eastern Sweden. The Forsmark area was compared with the other. Totally 38 different fish species were encountered in the different net catches. Additionally 12 species were caught at Forsmark nuclear power plant impinged on the travelling screens at the cooling-water intake. This makes a minimum of 50 fish species from this area of the Baltic Sea. The reason to the discrepancy between the two studies was most probably a low gill-net selectivity for small sized species. Generally, CPUE in the gill-nets varied with species, area, depth, net-type and temperature. CPUE of some of the most dominant warm-water species, like perch and roach, decreased with depths while CPUE of the cold-water species Baltic herring increased. There were relatively large differences between different coastal areas in catches. There were, however, small differences between the two areas close to Forsmark.

Attempts were made to calculate biomass (kg) per hectare for the fish community at Forsmark based on test-fishing and hydroacoustics. The uncertainty in these calculations, as well as variation in the results, is high due to e.g. species, year, season, depth and temperature. The differences in mean values between the two areas at Forsmark were, however, small. Based on the test-fishings, biomass in kg/ha was between 60 and 70. Hydroacoustics in combination with trawling resulted in an additional 40 kg of mainly sticklebacks and juvenile herring. It was, however, shown that aggregations of spawning herring may further increase the total biomass considerably.

Sammanfattning

Denna rapport redovisar en sammanställning av data som rör olika fiskarters förekomst och biomassa i kustområden längs ostkusten. Analysen är genomförd av Fiskeriverkets Kustlaboratorium på uppdrag av SKB. Data skall användas i den systemekologiska modell för havet utanför Forsmarksområdet, som upprättas i samband med platsbeskrivningen.

Variation i antal fiskar per ansträngning (CPUE) och artsammansättning har studerats med nät innehållande olika maskstorlekar (Kustöversikts-nät och Nordic-nät). Data från fem olika områden i Bottenhavet och ett i Stockholms skärgård analyserades. För SKB:s räkning jämfördes Forsmarksområdet med övriga. Totalt förekom i Forsmark 38 olika arter i nätfångsterna. Ytterligare 12 arter fångades i silstationerna till kraftverket. Således förekommer åtminstone 50 fiskarter i Forsmarksområdet. Skillnaderna mellan nätfångsterna och de i silstationerna beror sannolikt på nätens låga selektivitet mot framförallt småväxta arter. CPUE i näten varierade mellan arter, lokal, djup, nättyp och temperatur. CPUE för de dominerande varmvattenarterna, som abborre och mört, minskade med djupet medan det ökade för en kallvattenart som strömming. Skillnader i CPUE mellan områden var ganska stor. De två områdena nära Forsmark var emellertid förhållandevis lika i detta avseende.

Försök har gjorts att uppskatta biomassor av fisk per ytenhet baserat på provfisken och ekointegrering. Osäkerheten i sådana beräkningar är generellt sett stor vid omvandling av grunddata till biomassa per ytenhet. Till detta kommer även fångstvariationer med avseende på fiskart, år, säsong, djup och temperatur. Skillnaderna mellan de två Forsmarks-områdena var emellertid liten beträffande medelvärden. Baserat på nätprovfiskena låg dessa värden mellan 60 och 70 kg/ha medan ekointegreringen av pelagisk fisk uppgick till 40 kg/ha. Vid lekansamlingar av t ex strömming kan dock de totala värdena stiga avsevärt, vilket ekointegreringen i ett referensområde visade.

Contents

1 Introduction

This document reports the results gained by the study "Compilation of fish data", which is one of the activities performed within the site investigation at Forsmark. The work was carried out in accordance with activity plan AP PF 400-04-57 (activity plans are SKB's internal controlling documents). In Table 1-1 controlling documents for performing this activity are listed.

This study summarises data collected from fish investigations within the control program of the Forsmark nuclear power plant since 1991. Only data from areas not directly affected by the cooling-water outlets are used. Data consists of test-fishing with gillnets and yearly counting of fish that are impinged on travelling screens at the intake of cooling-water. These data are compared with new gill-net test-fishing data from south of the Forsmark power plant (Kallrigafjärden) as well as hydroacoustic studies. The two latter studies are mainly financed by SKB and reported as SKB reports /Abrahamsson and Karås, 2005; Axenrot and Hansson, 2005). The new gill-net test-fishing area lies within the area to be modelled by SKB. The results from the Forsmark area are further compared with nearby coastal areas using the same test fishing technique.

The data set compiled in this study has been stored in SKB's database SICADA and is traceable by the activity plan number (AP PF 400-04-57).

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	Number	Version
Sammanställning av fiskdata	AP PF 400-04-57	1.0

2 Objective and scope

The aim of this report is to give a characterisation of the coastal fish communities in the Forsmark area. The results will be used in an ecosystem model of this coastal area. The data will be used as input material to the safety analyses and environmental impact assessments for the potential deep repository of used nuclear fuel.

This report presents data on species composition, abundance and biomass/hectare for different functional groups of fish in the Forsmark (FM) and Kallrigafjärden (KF) area (Figure 2-1, Figure 2-2A and B). Data on species composition and catch per unit effort (CPUE) based on number of fish are also given. For comparison other test-fished coastal areas are included in the study; Finbo (FB), Lagnö (LG), and Långvindsfjärden (LF) (Figure 2-2C, D and E). Since the data in this report will be used in a whole system model for analysis of risk assessment, it is important to include information on the weakness or strength of the data. Therefore, to begin with a general view is presented of different factors which affect species abundance in CPUE (net-type, time of fishing, depths, area and temperature). After that, efforts to calculate biomass per hectare are presented.

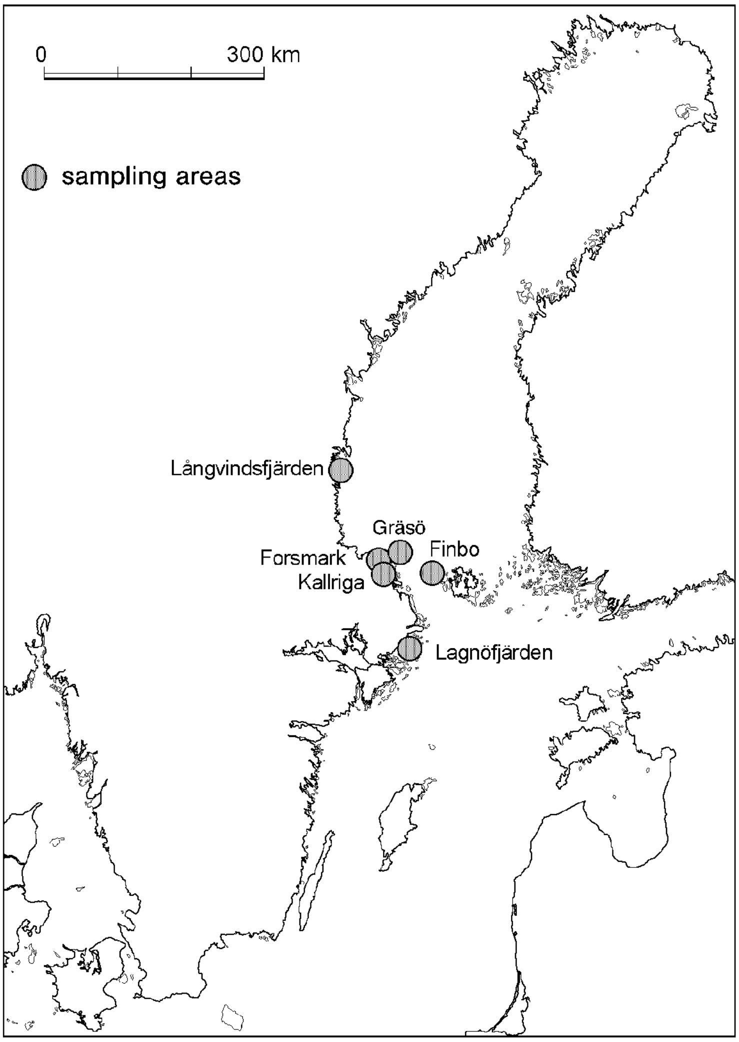
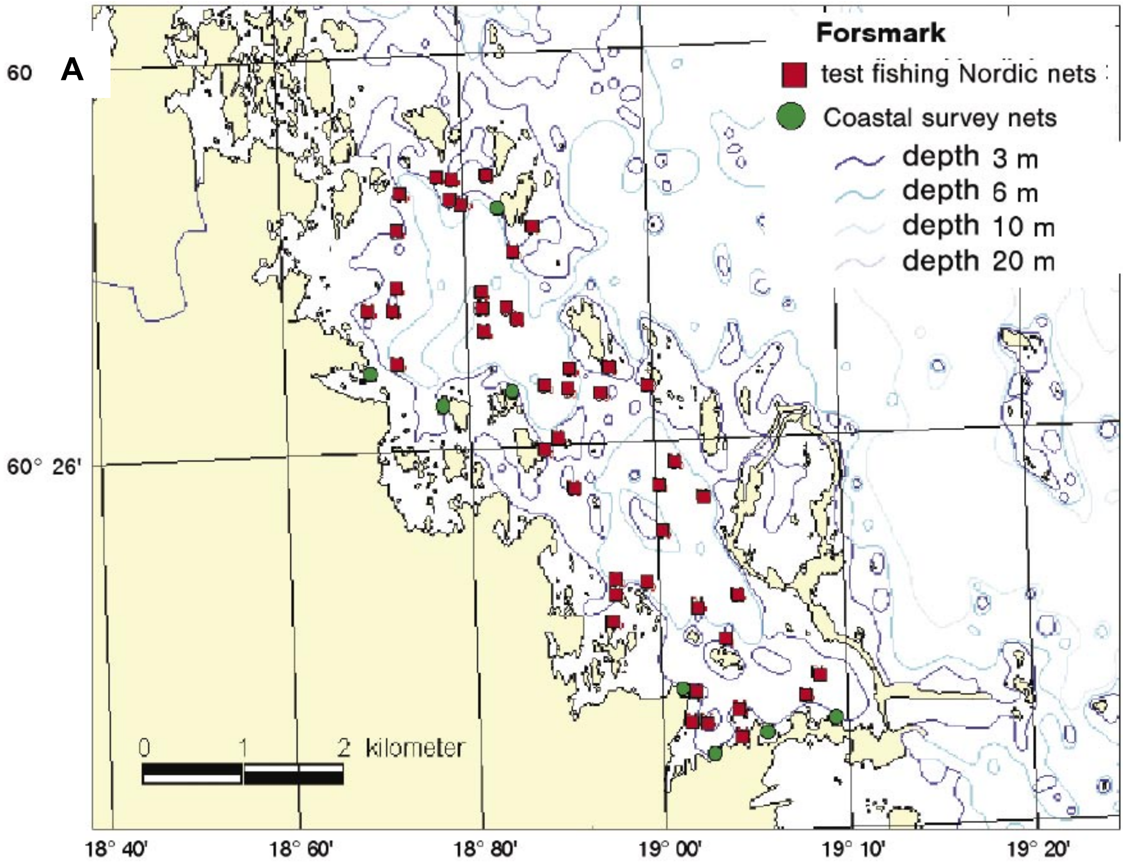


Figure 2-1. *Study areas.*


A
Forsmark
test fishing Nordic nets
Coastal survey nets
depth 3 m
depth 6 m
depth 10 m
depth 20 m
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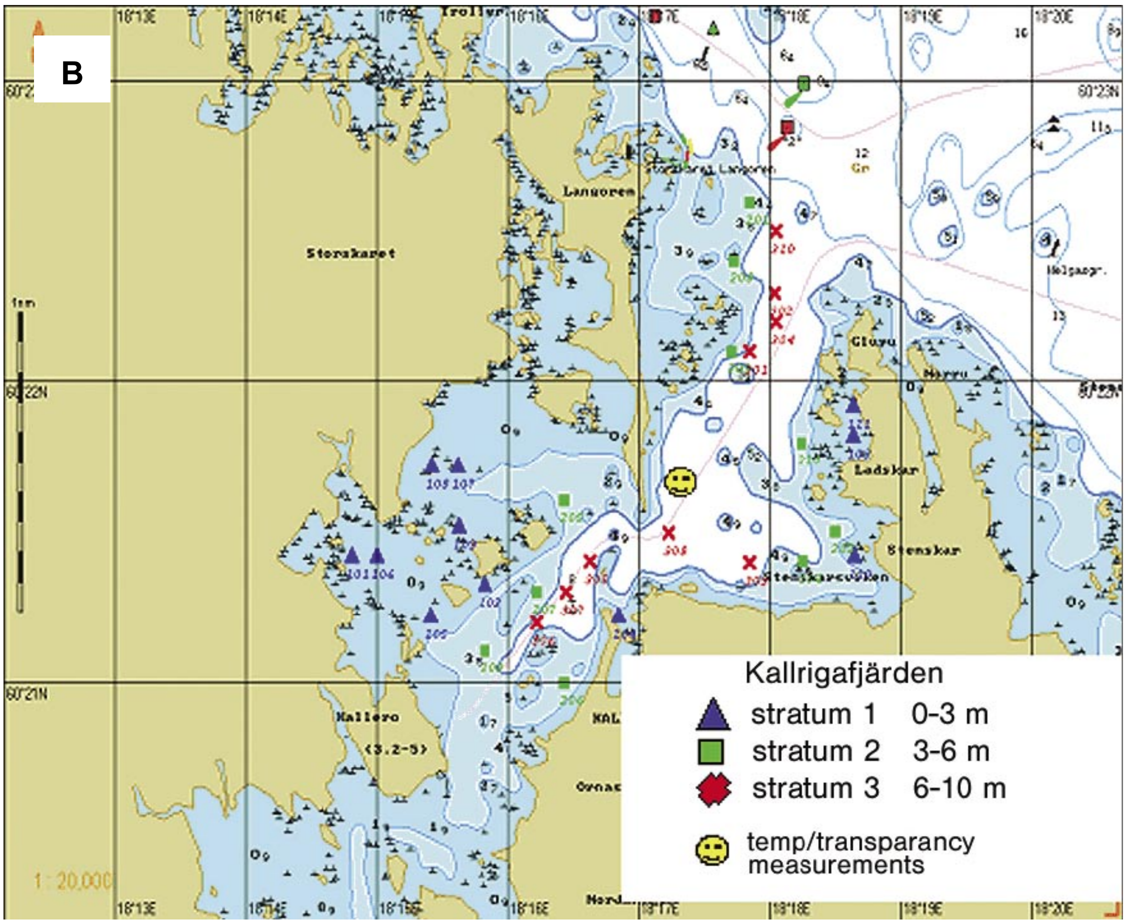
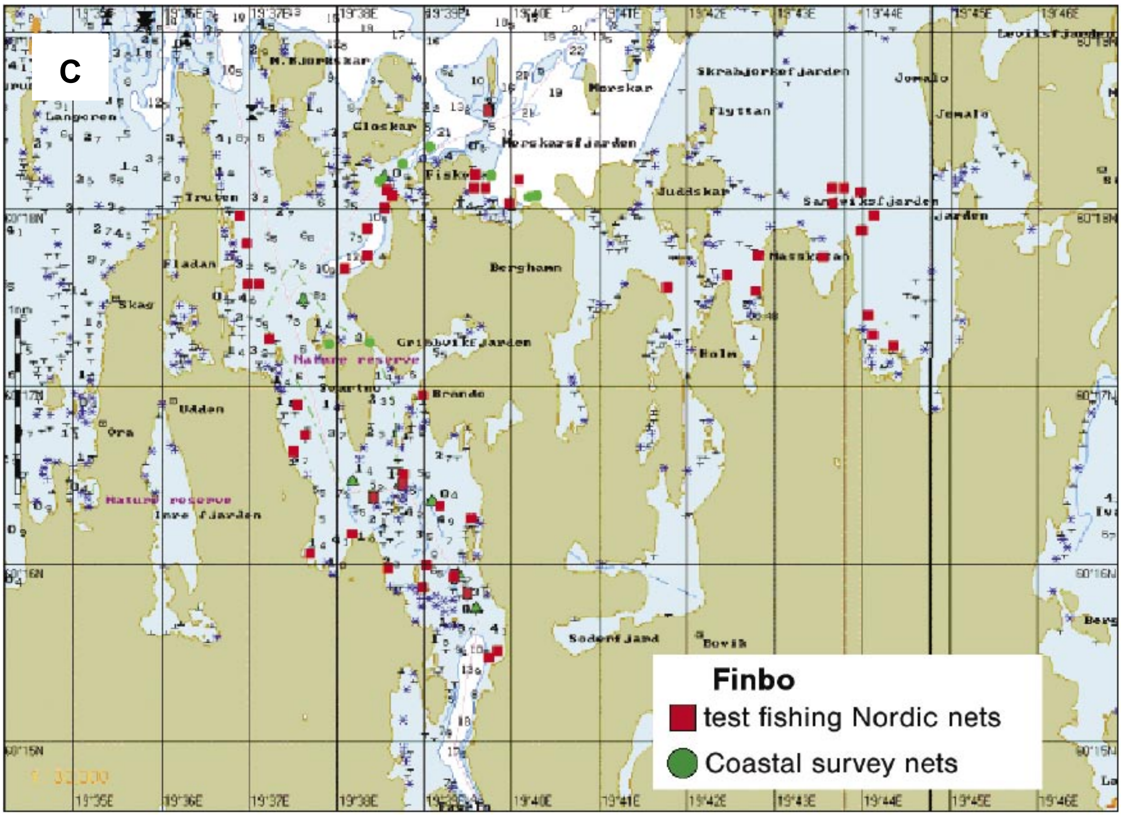
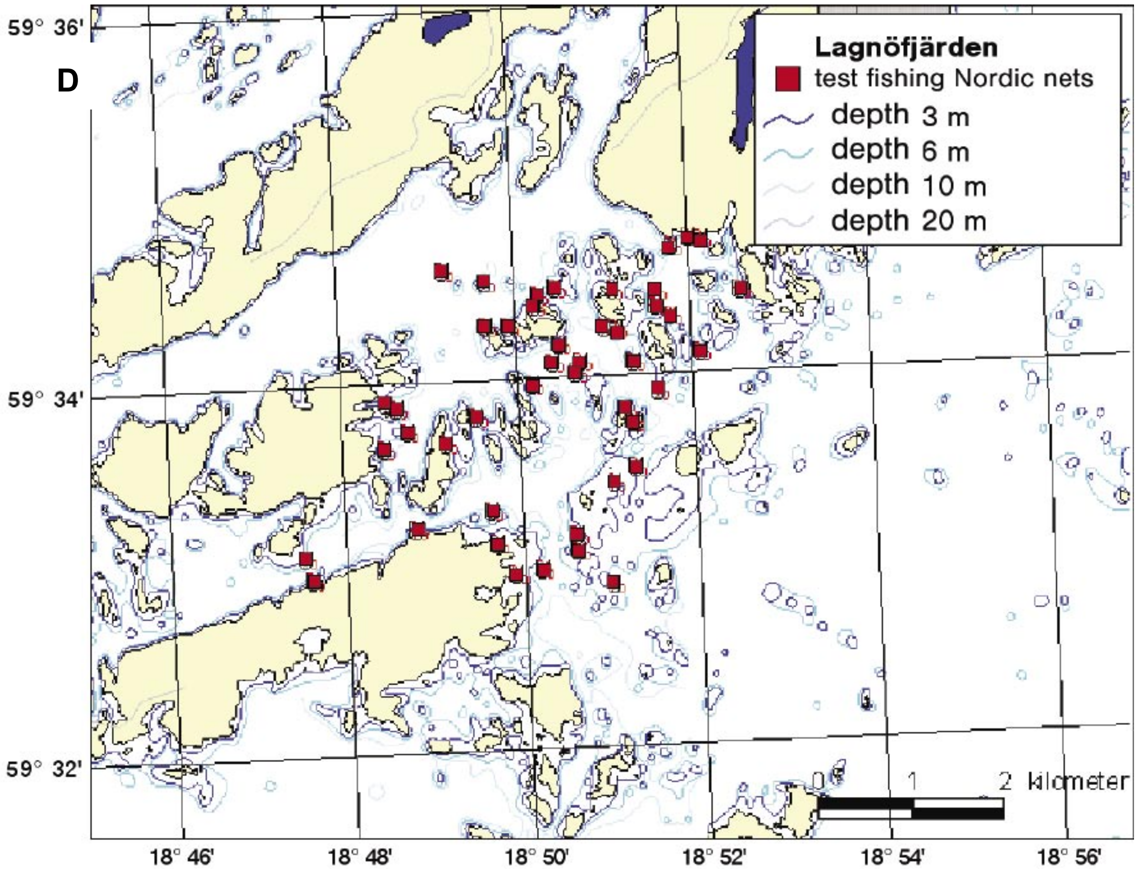
18° 40'
18° 60'
18° 80'
19° 00'
19° 10'
19° 20'


B
Kallrigafjärden
stratum 1 0-3 m
stratum 2 3-6 m
stratum 3 6-10 m
temp/transparancy measurements
1: 20,000


C
Finbo
test fishing Nordic nets
Coastal survey nets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test fishing Nordic nets
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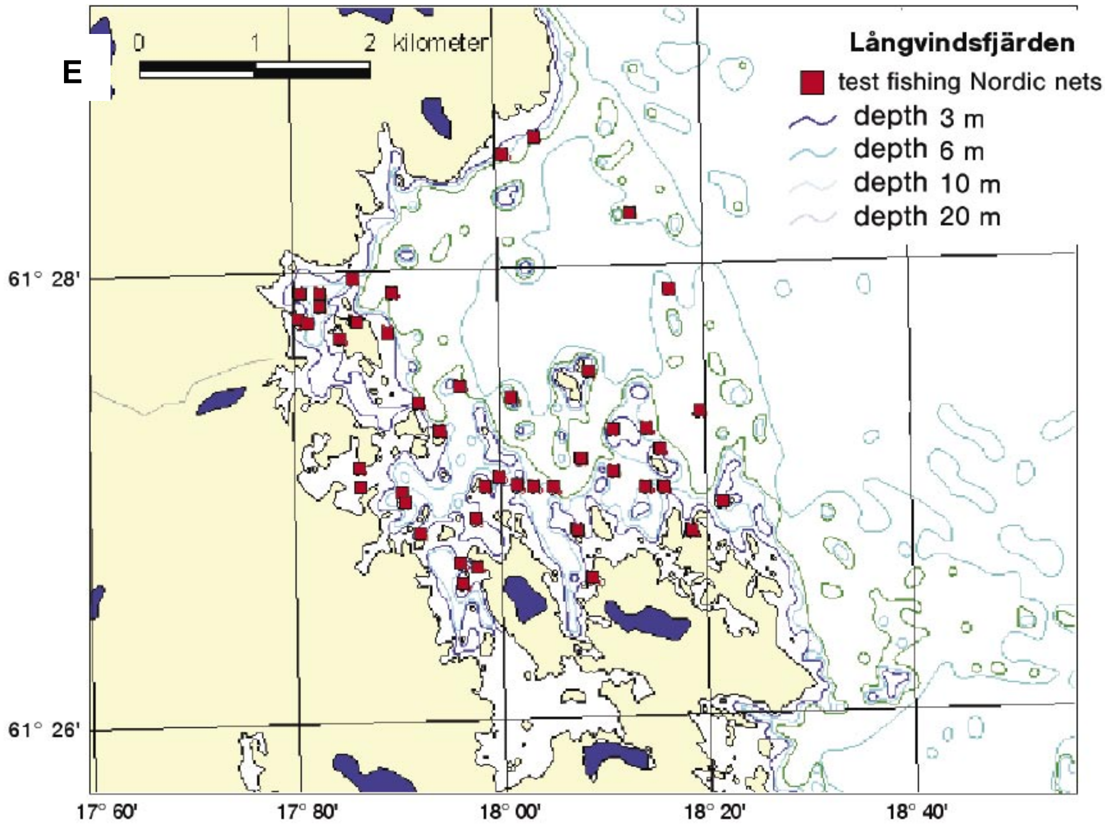

Figure 2-2. *Test-fishing stations at A. Forsmark, B. Kallrigafjärden, C. Finbo, D. Lagnö and E. Långvind.*

3 Material and methods

The material used to describe the fish community at Forsmark includes test-fishing with two kinds of multi-mesh nets (Coastal survey nets and Nordic nets). A hydroacoustic study /Axenrot and Hansson, 2005/ and catch of fish at the intake of cooling water of the power plant are also used in this respect. The test fishings give catch per unit effort (CPUE) based on number of fish. The Nordic net test-fishing is used to calculate biomasses of fish for functional groups.

3.1 Test-fishing

Coastal survey nets

Close to the Forsmark (FM) power plant a test fishing system has been running in autumn (August/September) since 1991 within the control program of the plant. These studies target species with relatively high temperature preference (further called warm-water species, see Table 3-1). The Coastal survey nets used are 3 metres high and 35 metres long gillnets with five panels of different mesh sizes (17, 22, 25, 33, and 50 mm). The effort is eight nets fished six nights at different stations within the area (Figure 2-2A). We excluded the four net stations south of the Biotest basin in all the statistical analyses since this section has been influenced by cooling-water. This was most pronounced in 1991 when the reserve pipe from the basin was open for research purposes /Svedäng and Karås, 1993/. The nets used are set between two and five metres in depth. They are set before sundown and lifted the next morning, resulting in an exposure for approximately 16 hours. Finbo (FB) at Åland (Figure 2-2C) is used as a reference area for the Forsmark studies. This area was fished between 1976 and 2003 with the same set-up, but the total effort was higher. Between 1976 and 1982 fishing was also performed outside the August/September period.

In addition, a test fishing for species with relatively low temperature preference (further called cold-water species) was performed at Forsmark in mid October from 1994 to 2002 with the same set-up as for warm-water species (Figure 2-2A). The archipelago east of the close by island of Gräsö (GÖ) was used as a reference area for this study from 1989 to 2001 (Figure 2-1). For more detailed information of this test-fishing system, see /Thoresson, 1996/ and especially the control program /Thoresson, 1992/. For comparison to the Nordic nets (see below), the Coastal survey nets are defined as belonging to the 3–6 metres depth zone.

The Coastal survey net system was especially developed for recipient monitoring. To optimize cost and labour, focus is on a special section of the fish community. Thus, the number of mesh-sizes is reduced and only one depth stratum is used.

Table 3-1. Fish species caught in gill-net fishing and data collected at Forsmark nuclear power station. Presence at Forsmark is also given.

Code	English name	Swedish name	Latin name	Functional group, Adults	Limnic warmwater species	Caught in Forsmark Area
Abbo	European perch	Abborre	*Perca fluviatilis*	Fac P	yes	yes
Besi	Alpine bullhead	Bergsimpa	*Cottus poecilopus*	B	no	GÖ
Björ	Silver bream	Björkna	*Abramis bjoerkna*	B	yes	yes
Blål	Silver eel	Blankål	*Anguilla Anguilla*	Fac P	no	yes
Brax	Bream	Braxen	*Abramis brama*	B	yes	yes
Elri	Minnow	Elritsa	*Phoxinus phoxinus*	B	no	yes
Färn	European chub	Färna	*Leusciscus cepahlus*	B	yes	yes
Flne	Lamprey	Flodnejonöga	*Lampetra fluviatilis*	Parasitt	no	yes
Gers	Ruffe	Gers	*Gymnocephalus cernuus*	B	yes	yes
Guål	Yellow eel	Gulål	*Anguilla Anguilla*	Fac P	no	yes
Gädd	Northern pike	Gädda	*Exox lucius*	Obl P	yes	yes
Gös	European pike-perch	Gös	*Sander lucioperca*	Obl P	yes	yes
Hosi	Fourhorned sculpin	Hornsimpa	*Triglopsis quadricornis*	B	no	yes
Hogä	Garfish	Horngädda	*Belone belone*	Fac P	no	yes
Id	Ide	Id	*Leuciscus idus*	B	yes	yes
Lake	Burbot	Lake	*Lota lota*	Obl P	no	yes
Lax	Salmon	Lax	*Salmo salar*	Obl P	no	yes
Miha	Straight-nosed pipefish	Mindre Havsnål	*Nerophis ophidion*	Z	no	yes
Löja	Bleak	Löja	*Alburnus alburnus*	Z	yes	yes
Mört	Roach	Mört	*Rutilus rutilus*	B	yes	yes
Nors	Smelt	Nors	*Osmerus eperlanus*	Z	no	yes
Oxsi	Longspined bullhead	Oxsimpa	*Taurulus bubalis*	B	no	FB
Piva	Turbot	Piggvar	*Psetta maxima*	Fac P	no	FB, GÖ
Rebå	Rainbow/Steelhead trout	Regnbåge	*Onchorhynchus mykiss*	Fac P	no	yes

Code	English name	Swedish name	Latin name	Functional group, Adults	Limnic warmwater species	Caught in Forsmark Area
Ruda	Crusian carp	Ruda	*Carassius carassius*	B	yes	yes
Rösi	Shorthorn sculpin	Rötsimpa	*Myoxocephalus scorpius*	Fac P	no	GÖ
Sarv	Rudd	Sarv	*Scardinius erythrophthalmus*	B	yes	yes
Sik	Baltic whitefish	Sik	*Coregonus lavaretus*	B	no	yes
Silö	Vendace	Siklöja	*Coregonus albula*	Z	no	yes
Sjry	Lumpsucker	Sjurygg	*Cyclopterus lumpus*	B	no	yes
Sksi	Sprat	Skarpsill	*Sprattus sprattus*	Z	no	yes
Sksk	Flounder	Skrubbskädda	*Platichthys flesus*	B	no	yes
Smsp	Nine-spined stickleback	Småspigg	*Pungitius pungitius*	O	no	yes
Ssim	Bullhead	Stensimpa	*Cottus gobio*	B	no	yes
Strö	Baltic herring	Strömming	*Clupea harengus*	Z	no	yes
Stäm	Dace	Stäm	*Leuciscus leuciscus*	B	yes	?
Stsp	Three-spined stickleback	Storspigg	*Gasterosteus aculeatus*	B	no	yes
		Sandstubb och lerstubb				yes
Hanå	Snake pipefish	Större Havsnål	*Entelurus aequoreus*	B	no	FB
Suta	Tench	Sutare	*Tinca tinca*	B	yes	yes
Svsm	Black goby	Svart smörbult	*Gobius niger*	B	no	yes
Tobi	Lesser sandeel	Tobis	*Ammodytes tobianus*	Z	no	yes
Toku	Greater sandeel	Tobiskung	*Hyperoplus lanceolatus*	Fac P	no	FB, GÖ, LG
Tors	Cod	Torsk	*Gadus morhua*	Fac P	no	FB, GÖ
Tåla	Eel-pout, Viviparous blenny	Tånglake	*Zoarces viviparus*	B	no	yes
Tåsn	Broad nosed pipefish	Tångsnälla	*Syngnthus typhle*	Fac P	no	FB
Tåsp	Sea stickleback	Tångspigg	*Pungitius pungitius*	B	no	yes
Ribu	Striped seasnail	Vanlig ringbuk	*Liparis liparis*	B	no	yes
Vimm	Vimba	Vimma	*Abramis vimba*	B	yes	yes
Örin	Brown trout	Öring	*Salmo trutta*	Fac P	no	yes

Nordic nets

At Forsmark, a parallel test-fishing to the Coastal survey net system was performed from 2001 to 2003 with another system that covers more depths and where each station is only fished once. These studies were not included in the control program of the power plant. They are instead part of a project developing a general monitoring program for coastal fish stocks in Swedish coastal waters of the Gulf of Bothnia. The aim of this system is to cover as large section of the fish community as possible. Thus, as compared to the Coastal survey nets, a larger set of mesh-sizes is used as well as more depth strata. The nets used in this system are 1.83 m high and 45 m long gill-nets with nine panels of different mesh sizes (10, 12, 15, 19, 24, 30, 38, 47, and 60 mm). Four different depth strata are normally fished in this system: 0–3 m, 3–6 m, 6–10 m and 10–20 m. The effort at the shallowest strata was during the studied period between 4 and 14 nets per night, the next 5 or 16 nets per night and 6–10 m 15 to 25 nets per night. The deepest stratum normally used in this system is not fished in the Forsmark area.

Several other coastal areas were chosen for comparison with the Nordic fishing at Forsmark (Figure 2-1) in addition to the reference area at Finbo, Åland (Figure2-2C, fished from 2002 to 2004). They were: Lagnö (LG) (fished from 2002 to 2004), Långvindsfjärden (LF) (fished from 2002 to 2004), and Kallrigafjärden close to Forsmark (KF, only fished in 2004) (Figure 2-2B–D). These areas were fished in the same manner as in the Forsmark study. However, variation in fishing effort was slightly different with a range from 5 to 19 nets per night for these areas. This is due to the fact that the number of stations depends on the area of the actual stratum. One study was performed in October 2001 at Gräsö with the purpose of targeting cold-water fish species. For more detailed information of the Nordic net system, see /Söderberg et al. 2004/. Temperatures were measured in both systems at the surface and catch depth in all fishings. At the same time the water visibility was measured with a Secci disc.

3.2 Calculations of CPUE and biomass/ha

Catch Per Unit Effort (CPUE) was defined as the number of fish per night. One net-night was approximately 16 hours of fishing and the net area in the Nordic nets was 82.35 square metres. Coastal nets have a fishing area of 105 square metres and therefore the catches were multiplied with 0.7843 to standardize CPUE in numbers. Biomass calculations were made on data from the Nordic nets and based on weight of fish per net and night of fishing.

Estimate of biomass per hectare were calculated for all species by multiplying biomass per Nordic net and night of fishing with the constant 17. This approximation was made from the relation between density of perch and CPUE in Costal survey nets. The estimate of density was based on a mark-recapture study of perch in the 90 hectare Biotest basin at Forsmark in 1996 (Gunnar Thoresson, unpublished manuscript). In this study the population density per hectare was 222 individuals/hectare of both sexes for perch over 15 cm or 19.6 kg per hectare. CPUE in Costal survey nets was at the time 13.4 for perch and dividing 222 by 13.4 thus gives a constant of 17.

3.3 Fish impinged at the cooling-water intake of the power plant at Forsmark

The Forsmark nuclear power plant uses about 90 m^3/s of cooling water in a once-through cooling system for the reactors 1 and 2. A variety of organisms of different sizes are included in this water. To avoid damages on the cooling-water system, large organisms are filtered off on travelling screens at an intake building. The mesh size of the screens at Forsmark is 2 mm. Thus, a lot of fish of mainly small sizes are filtered off. The abundances of these are studied within the control program of the plant. These data can complement the test-fishing with gill-nets to get a better picture of the fish community within the Forsmark area. Fish counting is performed in spring (week 17 to 24) and in autumn (week 37 to 48) with sampling two times per week. All fishes during these two days are counted. The data presented here represents the total numbers for these days during the two periods.

3.4 Hydroacustics

Fish abundance, biomass, densities and species composition were investigated at Forsmark using hydroacoustics and trawling, and by sampling temperature data. The method used is presented in /Axenroth and Hansson, 2005/. The studies were performed twice, in May and August/September 2004. The results from Forsmark were compared with two reference areas, NW Öregrund and NE Gudinge.

3.5 Functional groups

To designate a major functional group to a species may be difficult and perhaps subjective, since the diet diversity is large between individuals and also between populations of a species and even at different life stages. An example is given here for perch at Forsmark (Figure 3-1).

Young-of-the-year perch in the Forsmark area feed on zooplankton in the pelagic habitat during their first months. In general, perch shift habitat to the littoral zone in late summer /Byström et al. 2003/. During this phase they gradually change to feed on macro invertebrates. Production of large crustaceans (Isopods and Amphipods) is high in Baltic coastal waters and these food items can dominate also among large perch. Individual fish often, however, perform a second ontogenetic niche shift, changing from a benthivorous to a piscivorous stage. Differences between years can, however, be large /Karås, 1984/.

Data on perch from the Forsmark area demonstrate that exclusively dividing species into the three functional groups planctivorous, piscivorous and bentivorous is too general. More or less all species seem to have an early planctivorous life stage and we therefore group only the species adult life stage (Table 3-1). Since the amount of piscivory may vary greatly between individuals and populations in some species, we use the concept facultative or obligate piscivorous /Wootton, 1990/. The species were divided into functional groups according to the adult diet given in /Pethon, 1985/ and /Karås, 1979, 1984/.

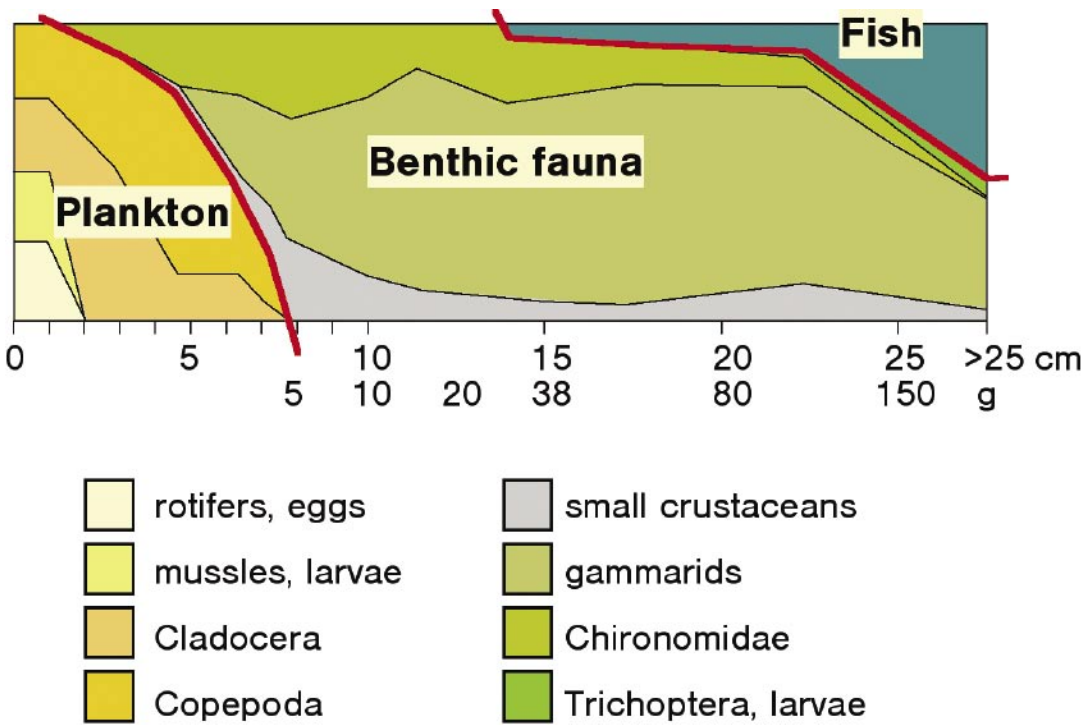

Figure 3-1. *Food preference of perch at Forsmark (Biotest basin) in 1980 /after Karås, 1984/.*

4 Results

4.1 Species composition

A total of 50 species were caught in the different areas (Table 3-1). In the gill-net test-fishing at Forsmark a total of 38 different species appeared . The dominating species were Eurasian perch, ruffe, roach, herring, whitefish, pikeperch and silver bream (Table 4-1). The studies of fish impinged at the cooling-water intake of the power-plant resulted in an additional 12 species (Table 4-2). In that study small sized and young fish living pelagically dominated.

Table 4-1. Mean values of CPUE with SD (±) for different net types and different time of year for the five most abundant species. Only statistically significant differences are given.

Species	Nordic nets	Coastal nets	August	October
Eurasian perch	29.6 ± 22.4	19.1 ± 16.2	29.8 ± 19.2	3.7 ± 2.9
Roach	12.9 ± 20.6	7.0 ± 5.5		
Ruffe	4.0 ± 2.1	1.7 ± 2.0		
Silver bream	2.0 ± 1.7	0.8 ± 1.2	1.6 ± 1.6	0.03 ± 0.03
Pike-perch	1.2 ± 1.0	0.2 ± 0.3	0.7 ± 0.8	0.14 ± 0.35

Table 4-2. Total number of fish impinged in the cooling-water intake to reactors 1 and 2 at Forsmark during two days a week in a spring respective autumn period.

Swedish name	English name	Spring Mean number/day 1987–2004	Autumn Mean number/day 1986–2003	Spring % 1987–2004	Autumn % 1986–2003
Storspigg	Three-spined stickleback	23,179.5	4,898.8	83.3	18.6
Strömming	Herring	1,489.3	18,861.8	5.4	71.7
Nors	Smelt	973.4	174.0	3.5	0.7
Småspigg	Nine-spined stickleback	722.1	1,377.7	2.6	5.2
Sand- och lerstubb	Small gobies	487.9	329.2	1.8	1.3
Löja	Bleak	330.7	125.1	1.2	0.5
Abborre	Eurasian perch	149.0	227.0	0.5	0.9
Mindre havsnål	Straightnosed pipefish	130.3	142.2	0.5	0.5
Kusttobis	Small sandeel	119.7	25.3	0.4	0.1
Gärs	Ruffe	71.8	10.2	0.3	0.0
Gös	Pike-perch	46.8	1.3	0.2	0.0
Mört	Roach	32.7	35.8	0.1	0.1
Svart smörbult	Black goby	22.9	0.8	0.1	0.0
Tångsnälla	Broadnosed pipefish	15.4	11.2	0.1	0.0
Tånglake	Viviparous blenny	13.4	0.7	0.0	0.0
Vimma	Vimba	6.7	3.3	0.0	0.0
Skarpsill	Sprat	6.5	38.8	0.0	0.1

Swedish name	English name	Spring Mean number/day 1987–2004	Autumn Mean number/day 1986–2003	Spring % 1987–2004	Autumn % 1986–2003
Björkna	Silver bream	4.4	6.6	0.0	0.0
Braxen	Bream	3.3	11.4	0.0	0.0
Ruda	Crusian carp	2.7	0.1	0.0	0.0
Flodnejonöga	Lamprey	2.4	0.6	0.0	0.0
Ål	Eel	1.7	3.6	0.0	0.0
Gädda	Pike	0.8	0.6	0.0	0.0
Bergsimpa	Alpine bullhead	0.1	0.0	0.0	0.0
Elritsa	Minnow	0.1	0.1	0.0	0.0
Hornsimpa	Fourhorned sculpin	0.1	0.1	0.0	0.0
Id	Ide	0.1	3.8	0.0	0.0
Lake	Burbot	0.1	0.1	0.0	0.0
Lax	Salmon	0.1	0.1	0.0	0.0
Piggvar	Turbot	0.1	0.1	0.0	0.0
Regnbåge	Steelhead trout	0.1	0.1	0.0	0.0
Sarv	Rudd	0.1	0.1	0.0	0.0
Sikar	White-fishes	0.1	1.9	0.0	0.0
Sjurygg	Lumpsucker	0.1	0.1	0.0	0.0
Skrubbskädda	Flounder	0.1	0.1	0.0	0.0
Sutare	Tench	0.1	0.1	0.0	0.0
Tångspigg	Sea stickleback	0.1	0.1	0.0	0.0
Vanlig ringbuk	Striped seasnail	0.1	0.1	0.0	0.0
Färna	European chub	0.0	0.1	0.0	0.0
Horngädda	Garfish	0.0	0.1	0.0	0.0
Torsk	Cod	0.0	0.1	0.0	0.0
Ullhandskrabba	Mitten crab	0.0	0.1	0.0	0.0
Öring	Brown trout	0.0	0.1	0.0	0.0

4.2 General results from test-fishings with gill-nets

4.2.1 Abiotic Factors

Mean visibility was significantly different between all areas (Figure 4-1A) (Anova, $F_{3,516} = 179.7$, $P < 0.0001$) in data from the Nordic nets and differences were large. Thus, at Långvindsfjärden (LF) it was 6.5 m and in Kallrigafjärden (KF) just over 3 m. The difference was, however, small between Forsmark (FM) and Kallrigafjärden.

There was no difference in mean temperature between areas or between years for data from the Nordic nets (Anova, $P > 0.05$). For these data from late summer mean temperature decreased with depth (Figure 4-1B) and temperature was significantly different between all depths (Anova, $F_{3,516} = 179.7$, $P < 0.0001$).

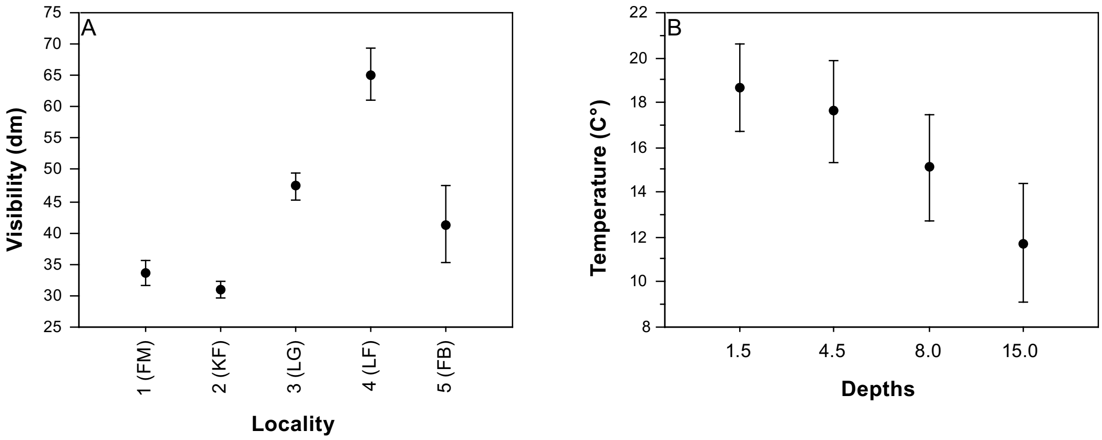

Figure 4-1. *A. Mean visibility ± SD for each locality in the Nordic survey fishing in August. B. Mean temperature ± SD for each depth zone in the Nordic survey fishing in August.*

4.2.2 Net type and CPUE

Generally the Nordic nets fished twice as many fish as the Coastal survey nets (see e.g. Table 4-1, Anova, $F_{1.1184} = 19.2$, $P < 0.0001$). CPUE was further about three times as high for warm-water species compared to cold-water species, but variation was large (Anova, $F_{1.1184} = 42.42$, $P < 0.0001$). In the further treatment of data variation in CPUE (ln transformed data) was analysed using a general linear model (GLM). The model used season, year, net-type, area, depths, visibility, net-temperature and species as predictor variables. After removing the non-significant higher order variables two variables remained that explained the data well with a significant whole model R^2 adjusted equal 0.67. The remaining variables were net-type ($F_{1,1148} = 157.8$, $P < 0,0001$) and species ($F_{36.1148} = 59.9$, $P < 0.0001$). Depths ($F_{3.1140} = 2.40$, $P = 0.07$) and area ($F_{5.1143} = 1.91$, $P = 0.09$) tended to have an effect in the model, but was not considered significant. Analysis in this section was performed on the complete dataset, but with Finbo-fishing from 1976 to 1982 excluded.

4.2.3 Net type, fishing season (August and October) and CPUE

The most abundant species were analysed with simple Anova's to show effect of net-type and time of fishing. Four warm-water species were used (perch, roach, pikeperch and silver bream) and two cold-water species (herring and Baltic whitefish). Ruffe, which has a temperature preference in between the other species, was also analysed. Mean CPUEs are given in Table 4-1.

Perch CPUE was nearly twice as high in the Nordic nets as in the Coastal survey nets ($F_{1.107} = 7.9$, $P = 0.006$). Catches in August were eight times higher for this species compared to October ($F_{1.107} = 41.8$, $P < 0.0001$).

Roach CPUE was also higher in the Nordic nets ($F_{1.104} = 4.2$, $P = 0.04$). Surprisingly roach CPUE showed no difference in the different months fished ($P = 0.08$). This could, however, be caused by the large variation in data.

Pikeperch CPUE was approximately five times higher in Nordic nets compared to Coastal nets ($F_{1.72} = 35.6$, $P < 0.0001$). CPUE in the August fishing's was also approximately five times higher than October fishing's ($F_{1.72} = 9.52$, $P < 0.003$).

Silver bream showed no difference in CPUE between type of nets ($F_{1.71}$ = 11.7, P = 0.001). This species had approximately sixty-two times higher CPUE in the August fishing compared to the October fishing ($F_{1.71}$ = 10.8, P = 0.0016).

Ruffe CPUE was more than twice as high in Nordic nets compared to Coastal nets ($F_{1.105}$ = 35.6, P < 0.0001). Like roach there was no difference in fishing time (P = 0.87).

Herring showed no significant difference in CPUE between time of fishing (P = 0.13) or between type of nets used during fishing (P = 0.78).

Baltic whitefish had approximately two times higher CPUE in Nordic nets ($F_{1.68}$ = 3.5, P = 0.065), but the difference was not significant. There were no significant difference in time of fishing (P = 0.1).

4.2.4 Depths and CPUE

To investigate the variation in CPUE between depths for different species, data were only used for species that appeared more than 25 times in the lowest unit in a study, namely station. A single Anova was performed for the remaining species. Only data from Nordic fishing's (2001–2004) in August was used in this analysis.

There were large differences in CPUE for different species at different depth zones (Figure 4-2). The general patterns for perch and roach were a decrease in number with increase in depth (perch: $F_{3,47}$ = 14.4, P < 0.0001, roach: $F_{3,44}$ = 6.3, P < 0.0012).

An opposite pattern with increasing numbers of fish with increase in depth was found for herring ($F_{3,40}$ = 5.4, P = 0.0033), Baltic whitefish ($F_{3,24}$ = 4.0, P = 0.0191), and smelt ($F_{3,67}$ = 9.8, P < 0.0001).

A pattern with the highest CPUE in the first depth zone, but with no significant decrease with depth, occurred for bream ($F_{3,24}$ = 3.25, P < 0.0391) and bleak ($F_{3,31}$ = 4.31, P = 0.012).

A pattern with the highest CPUE in the intermediate depth zones (4.5 and 7.5 m) appeared for ruffe ($F_{3,46}$ = 4.2, P = 0.011).

For silver bream, sprat, pikeperch, and pike, no significant differences in CPUE between depths were found (P > 0.05).

Some fishes were missing in deeper water. For pike, ide and black goby no fish was caught at the deepest catch depth 15 m. Rudd, bullhead and three-spined stickleback were not caught at depths 8 and 15 m.

In addition, some fishes were missing in shallow water. Eel-pout and fourhorned sculpin were only found at depths from 4.5 to 15m.

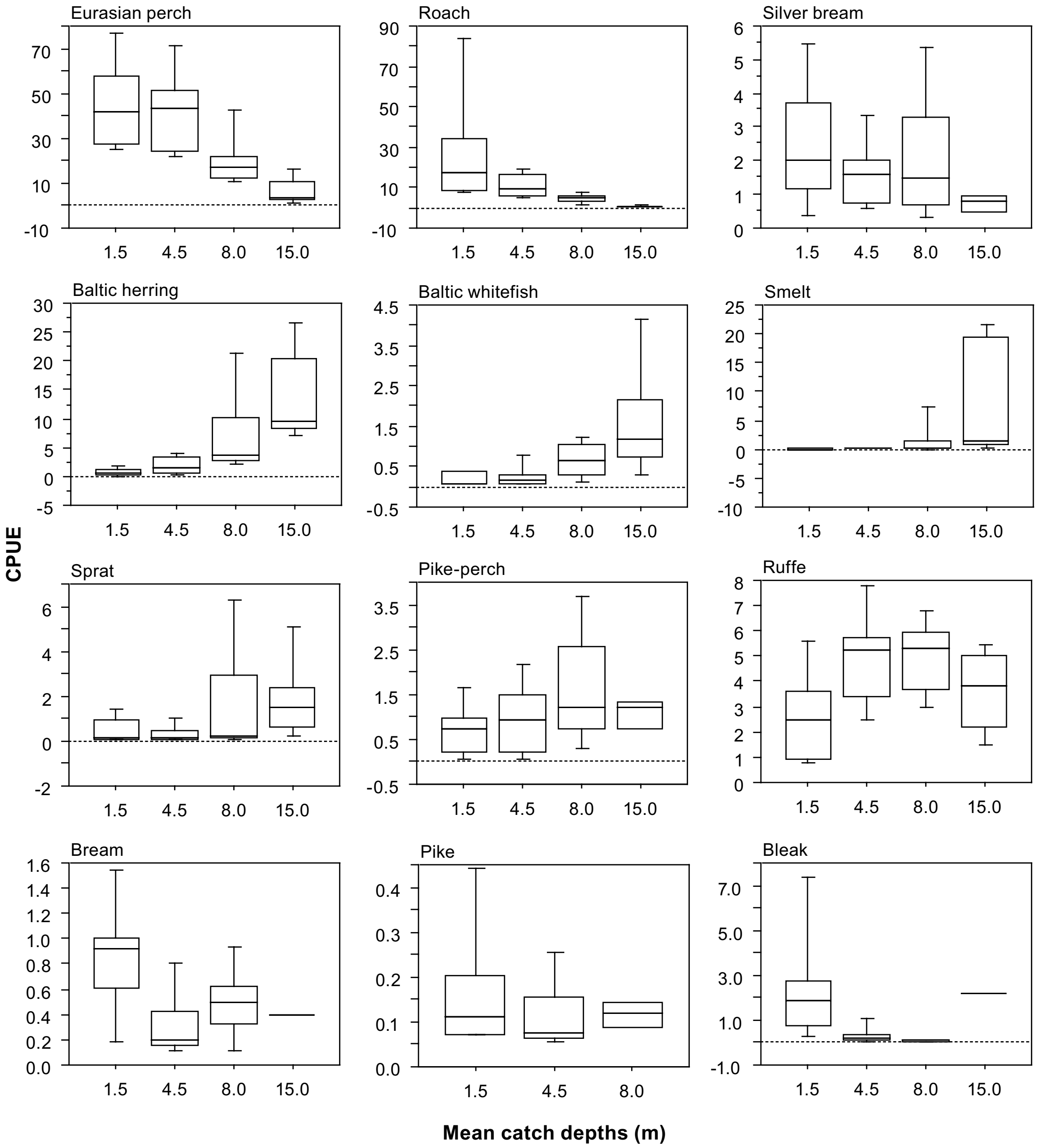

Figure 4-2. *Box-plot of CPUE at four depths for different species. For each depth zone the mean depth value is presented. The box shows the group median as a line across the middle and the quartiles (25th and 75th percentiles) as its ends. The 10th and 90th quantiles are shown as lines above and below the box. Data from Nordic survey fishing in August.*

4.2.5 Areas and CPUE

The effect of investigated area was studied on data from Nordic fishings. For some species there were large differences in CPUE in this respect (Figure 4-3).

Abundance and species composition were about the same in Kallrigafjärden (KF) and Forsmark (FM) in the Forsmark area (Figure 4-3). Furthermore, the length distributions of the dominating species, perch, also strongly resembled each other for the two areas (Figure 4-4). The largest differences in abundance between these areas at the Forsmark coast concerned ruffe ($F_{1,13} = 6.5$, $P = 0.0242$), which was more frequent at Forsmark.

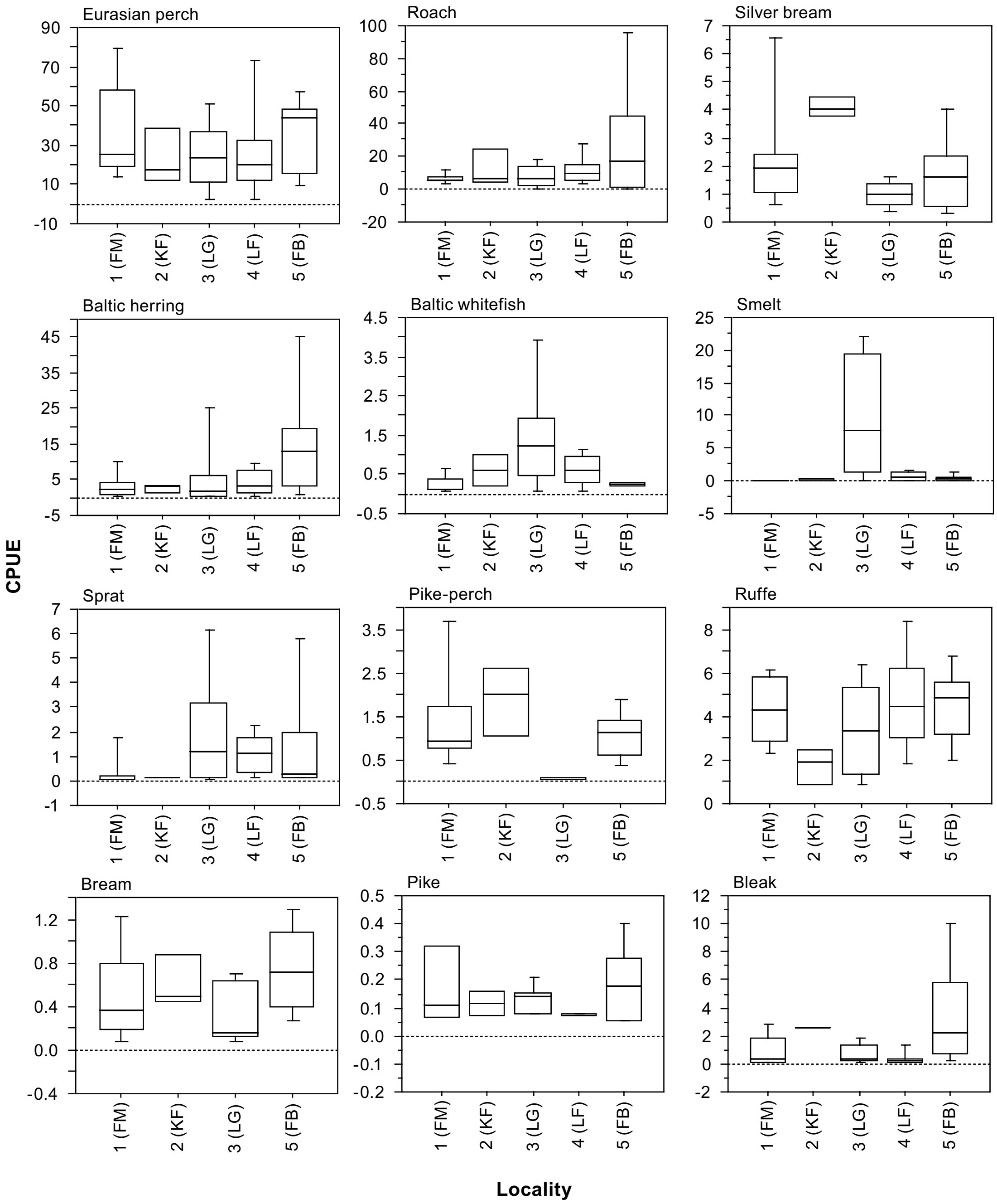

Figure 4-3. *Box-plot of CPUE for different species in different areas. Data from Nordic survey fishing in August.*

Further no ide, flounder, three-spined stickleback or black goby were caught in the nets in Kallrigafjärden while they were present at Forsmark. At Forsmark, no fourhorned sculpin, burbot, rudd, bullhead and tench were caught in the nets, while they were present in Kallrigafjärden.

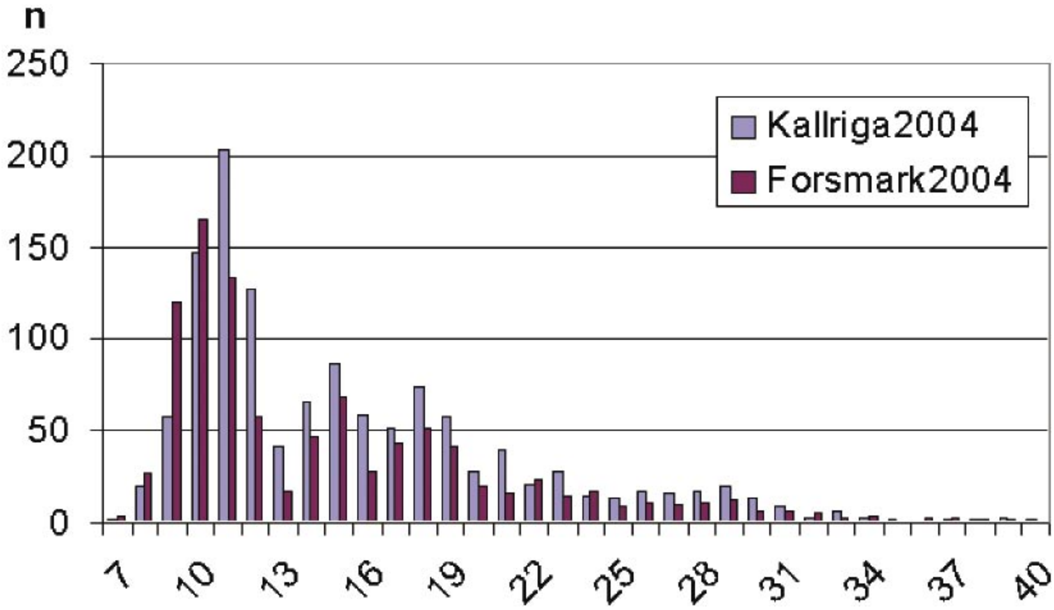

Figure 4-4. *Length distribution of perch from the two areas at Forsmark.*

A comparison between the two areas at the Forsmark coast and other areas shows larger differences than between the two Forsmark areas (Figure 4-3). Still due to small number of fishings, these differences are only significant for a few species. For example the Lagnö area (LG) has higher observed mean values of cold-water species as whitefish and smelt than the Forsmark area.

A number of species was only found in one area during net-fishing. These were alpine bullhead and shorthorn sculpin at Gräsö, crusian carp and three-spined stickleback at Forsmark, and straight-nosed pipefish, longspined bullhead, rainbow trout, snake pipefish and broad nosed pipefish at Finbo (Table 3-1).

4.2.6 Depth distribution and individual weight of fish

Since the Nordic test fishing is performed in different depth strata it was possible to study the mean weight of different species at different depths (Figure 4-5). For warm-water species as perch, roach and silver-bream these data show that the larger fish preferred deeper water and the smaller the shallowest water. Ruffe had a similar trend. There was no clear tendency for cold-water species as a whole, although e.g. whitefish showed an opposite trend compared to the warm-water species.

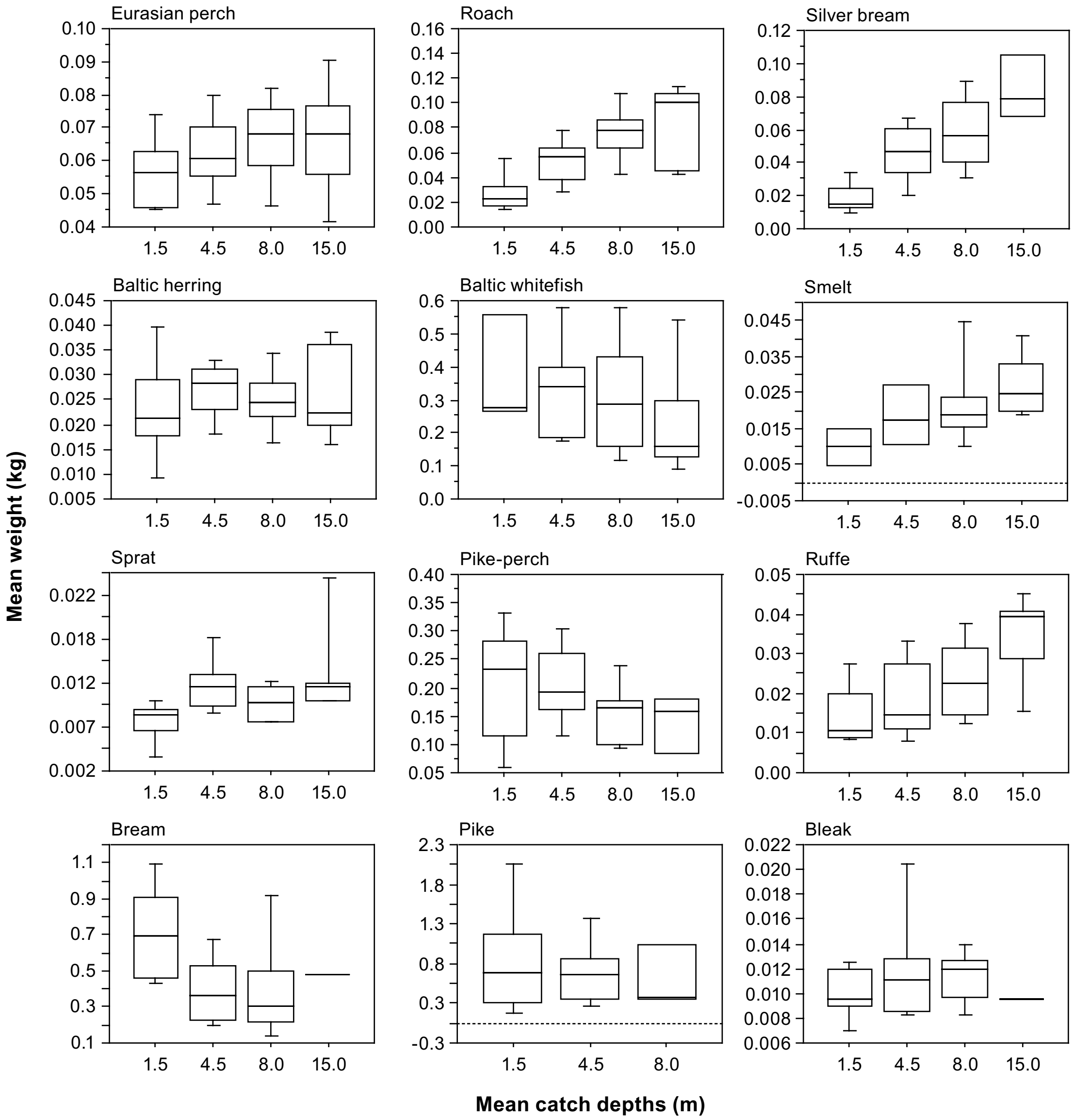

Figure 4-5. *Box-plot of individual weight of fish at each depth zone for the different species from the Baltic Sea area.*

4.2.7 Temperature and CPUE

CPUE of typical warm-water species as perch and roach showed a positive relation to temperature up to 22°C, while it was negative for a typical cold-water species as herring (Figure 4-6). Ruffe, which has intermediate temperature preferences, showed no trend in this respect.

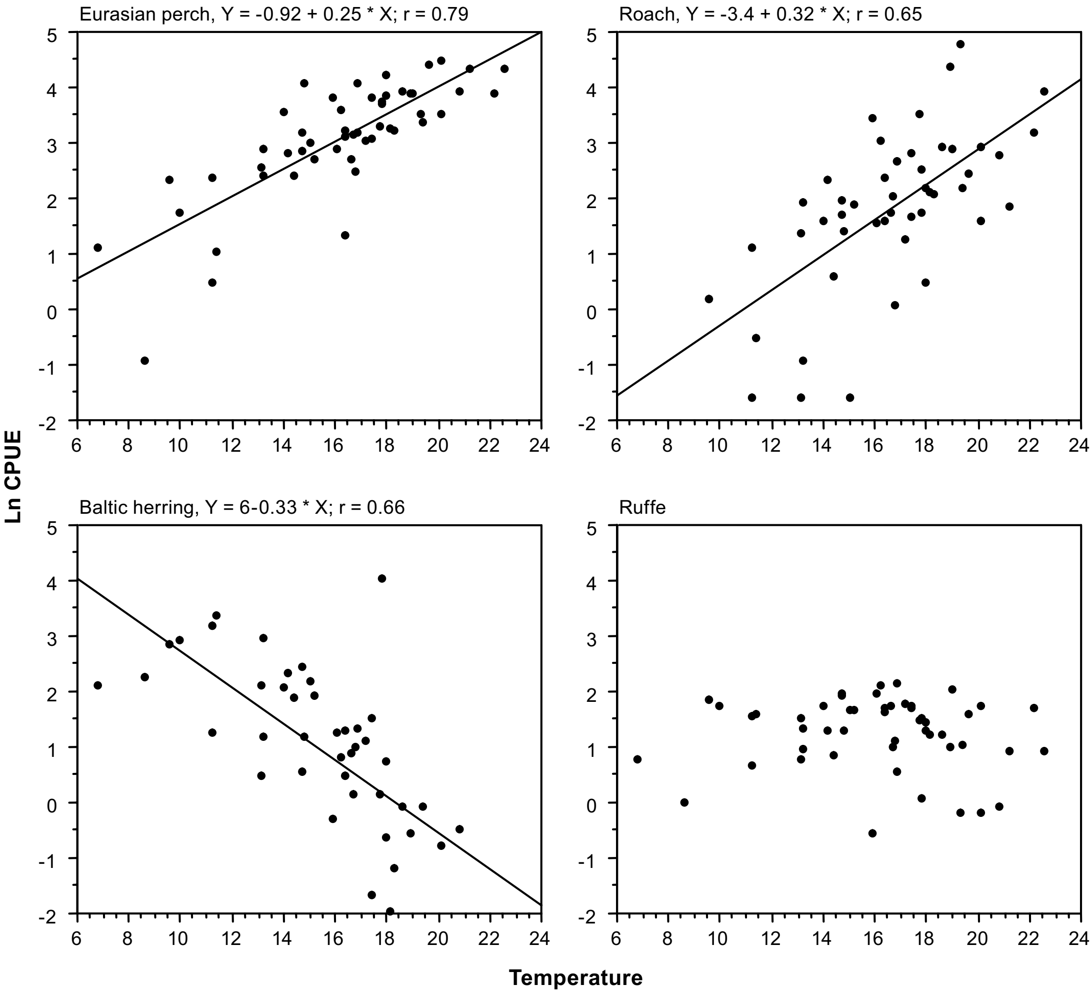

Figure 4-6. *Simple regressions with ln transformed CPUE against temperature at catch depths for the four most dominant fish species in Nordic survey fishing in August (five localities pooled).*

4.2.8 Inter-year variations and CPUE

The longer time series from the Coastal survey nets demonstrate large inter-year variations in CPUE for the four dominating fish species (Figure 4-7 and 4-8). At Forsmark there was a negative relationship between year and CPUE for Eurasian perch, but only from 1996 to the present day ($r_9 = 0.67$, $P = 0.049$). This was also the case for roach, but only from 1997 to the present day ($r_8 = 0.75$, $P = 0.032$). For Baltic herring and Ruffe there were no relationship of year and CPUE ($P > 0.05$). At Finbo on the other hand the relationships were positive for Eurasian perch (whole time series, $r_{28} = 0.87$, $P < 0.0001$) and roach (from 1992 to present, $r_{12} = 0.65$, $P = 0.022$). Ruffe showed no relationship ($P = 0.25$), but there was a negative one with Baltic herring at Finbo ($r_{28} = 0.61$, $P = 0.0005$). To some extent it seems that perch and herring have opposite developments. This was also evident concerning the relationship between Eurasian perch CPUE and Baltic herring CPUE which showed a negative relationship ($r_{42} = 0.57$, $P < 0.0001$).

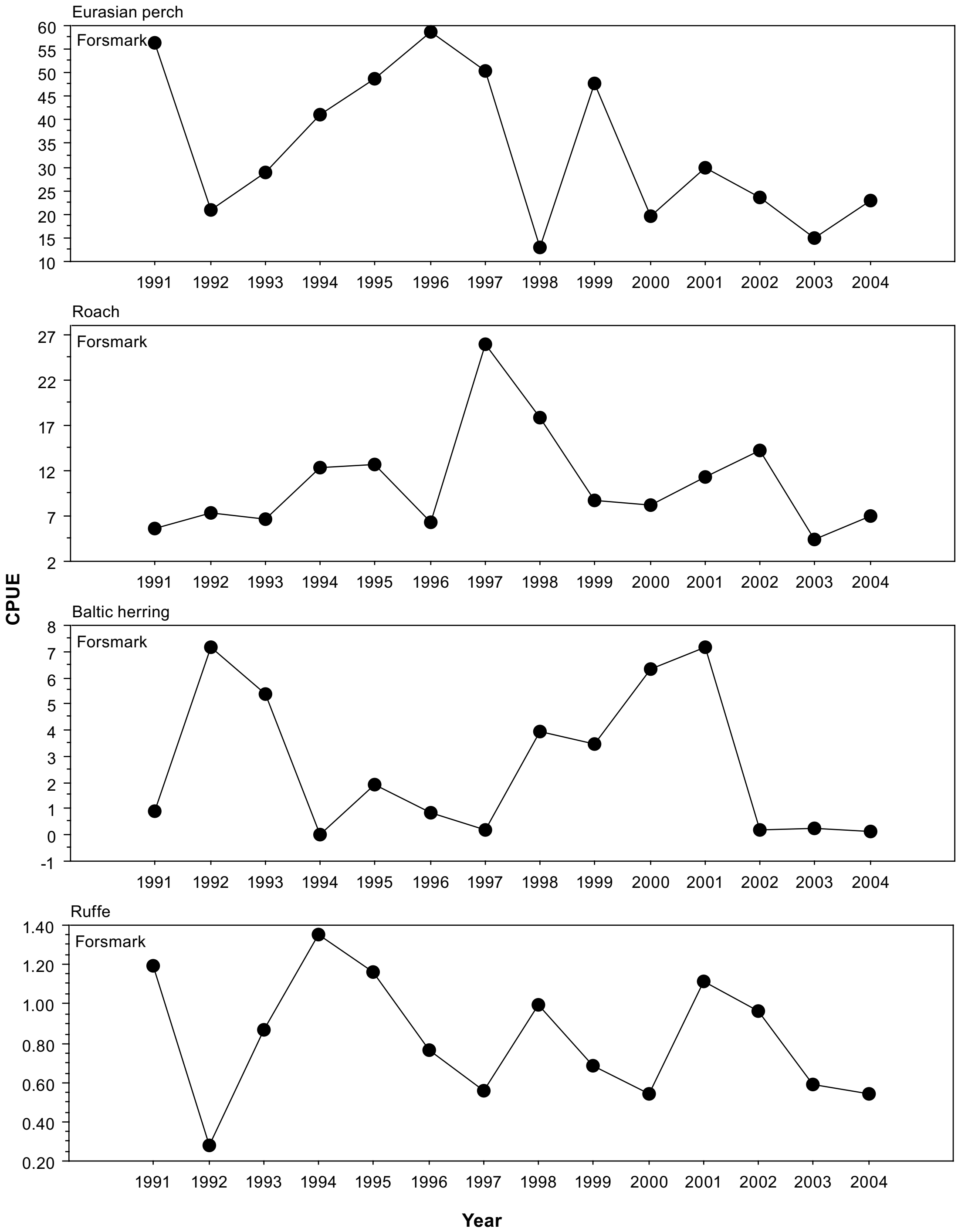

Figure 4-7. *CPUE between years during 1991 to 2004 for the four most dominant fish species in the Coastal survey fishing conducted at Forsmark locality in the Baltic Sea in August.*

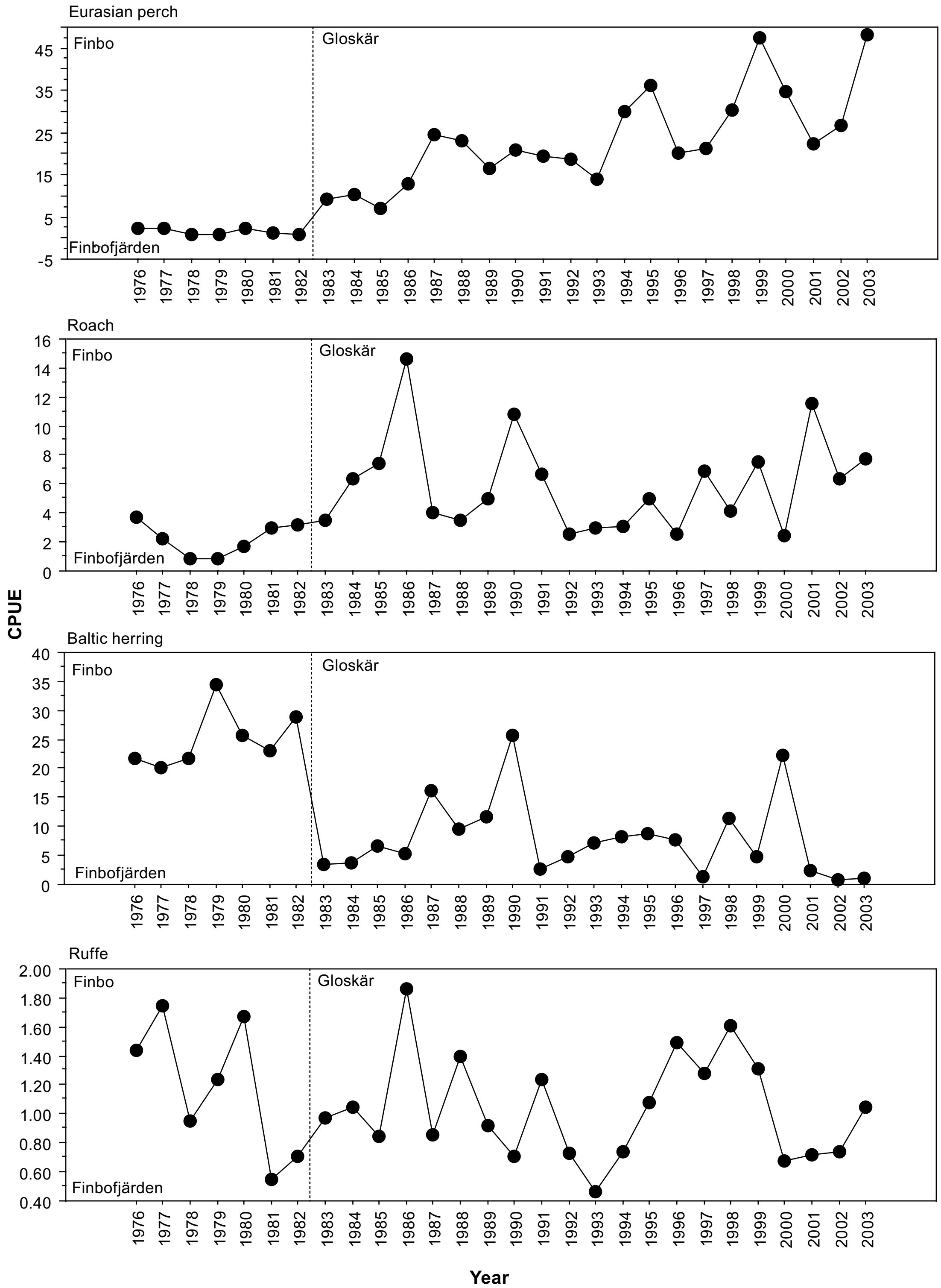

***Figure 4-8.** CPUE between years for the four most dominant fish species in Coastal survey fishing conducted at Finbo locality in the Baltic Sea in August. The dotted line indicates a change in the stations fished in the same manner as in Forsmark to make the areas comparable.*

4.2.9 Biomass of functional groups

Calculations of biomass per hectare for the different functional groups show that facultative piscivores as perch dominate (Table 4-3, 4-4 and 4-5, Figure 4-9 and 4-10). Although obligate piscivores as pike have higher mean weight, they occur in low numbers. There are, however, large variations in these estimates within the different test fishings, but also between them. The Coastal survey nets for warm water species and the Nordic nets, however, give about the same estimates (Figure 4-10, P = 0.37). Since the Nordic nets have information for different depths we used them in the further analysis.

Biomass per hectare for the different species in Kallrigafjärden and Forsmark gives about the same estimates (72.3 kg/ha and 61.5 kg/ha respectively, Table 4-3 and 4-4). The largest difference concerns tench with 10 kg/ha in Kallrigafjärden and no catch for Forsmark. Perch is totally dominating in both areas and constitutes about half the total biomass. A comparison to the other areas in this study also provides about the same values for the different areas, except for Långvindsfjärden where there are lower values for piscivores (Table 4-4). Differences between Kallrigafjärden and Forsmark mainly concern bentivores, which have lower values at Forsmark (30.5 kg/ha and 18 kg/ha respectively).
As pointed out earlier this is an effect of higher values for tench.

Biomass per hectare for functional groups in different depths in Kallrigafjärden and Forsmark differs between the two areas mainly for facultative piscivores (Table 4-5). Thus, in Kallrigafjärden they have highest values in the shallowest section while they are more evenly distributed within the whole 0 to 6 m depth interval at Forsmark.

4.3.1 Fish impinged at the cooling-water intake

The data from the gill-net test-fishing gives a biased representation of the total fish community, and this is especially true for small-sized and young fish. To complement the surveys, data from the studies of fish impinged at the cooling water intake was used. These data show high abundances of small sized and young fish of predominantly sticklebacks, herring, gobies and bleak (Table 4-2). Perch, straightnose pipefish, small sandeel, ruffe and pikeperch are also common species. A total of 43 species were caught.

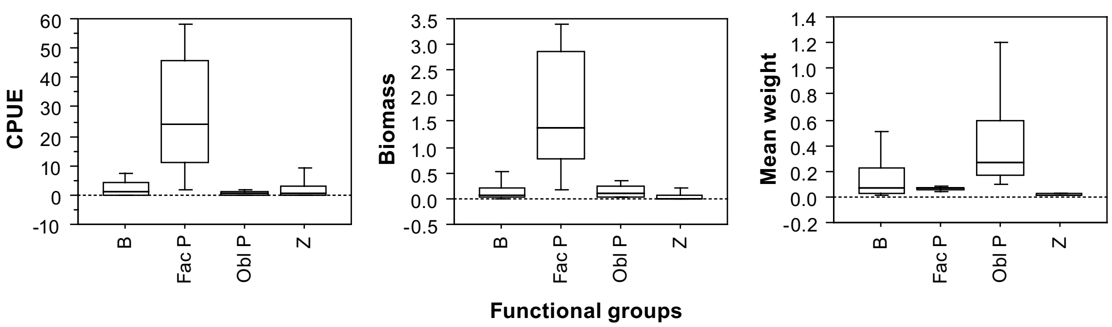

__Figure 4-9.__ Box-plot of the relative parameters CPUE, Biomass (kg) and mean weight (kg) of fish divided for the functional groups Bentivorous (B), Facultative Piscivorous, Obligate Piscivorous and Zooplanctivorous. Data from Nordic survey fishing in August (five localities pooled).

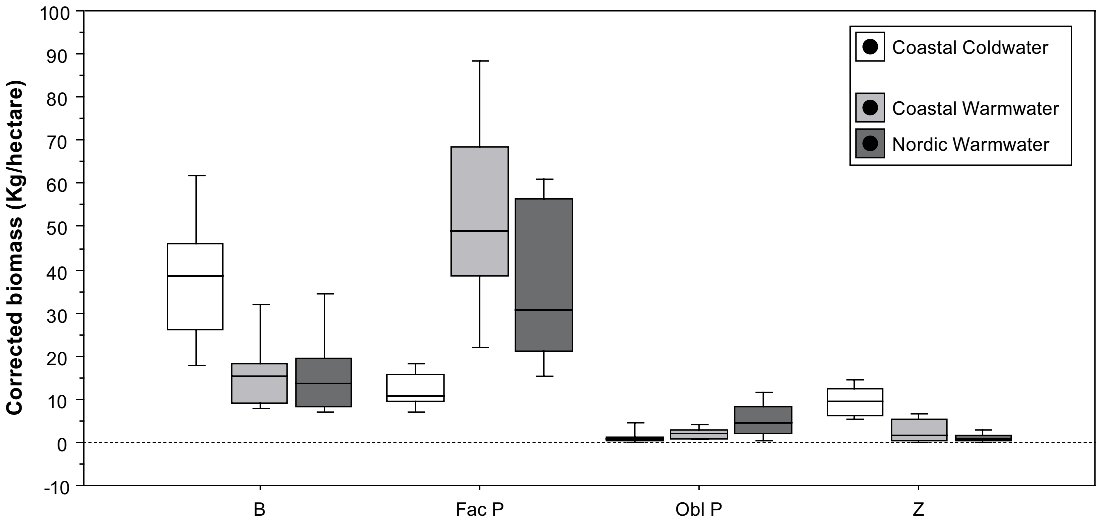

Figure 4-10. *Total biomass in kilogram/hectare for functional groups divided by net type and temperature preference group.*

Table 4-3. Calculated biomass for different species present in the Nordic survey fishing. (August at Kallrigafjärden (2004) and Forsmark (2001–2004)).

Species		Biomass KF 2004	Biomass FM 2001–2004
Eurasian perch	Abborre	30.212	34.101
Silver bream	Björkna	1.286	1.717
Bream	Braxen	5.384	4.630
Ruffe	Gers	0.412	0.933
Northern pike	Gädda	1.764	3.328
European pike-perch	Gös	6.629	3.618
Fourhorned sculpin	Hornsimpa	0.201	–
Ide	Id	–	3.448
Burbot	Lake	1.535	–
Bleak	Löja	0.394	0.129
Roach	Mört	5.889	4.472
Smelt	Nors	0.101	0.015
Rudd	Sarv	1.870	–
Baltic whitefish	Sik	4.976	2.377
Sprat	Skarpsill	0.023	0.071
Flounder	Skrubbskädda	–	0.228
Bullhead	Stensimpa	0.010	–
Baltic herring	Strömming	1.115	1.468
Three-spined stickleback	Storspigg	–	0.002
Tench	Sutare	10.465	–
Black goby	Svart smörbult	–	0.011
Eel-pout, Viviparous blenny	Tånglake	0.026	0.020
Vimba	Vimma	–	0.185
Eel	Ål	–	0.765
Total Biomass		72.3	61.5

Table 4-4. Calculated biomass for functional groups in different areas from Nordic survey fishing in August (2001–2004).

Locality	B	Fac P	Obl P	Z	Sum (Sum for each area)
Kallrigafjärden	30.5	30.2	9.9	1.6	72.3
Forsmark	18.0	34.9	6.9	1.7	61.5
Lagnö	31.0	32.4	1.6	5.9	70.8
Langviksfjärden	21.0	24.8	0.7	3.3	49.9
Finbo	24.6	36.7	8.2	6.4	76.0

Table 4-5. Calculated biomass for functional groups in different areas and depths from Nordic survey in August (2001–2004).

Locality	B	Fac P	Obl P	Z	Sum (Sum for each depth at area)
Kallrigafjärden 0–3	33.2	54.0	7.4	0.7	95.4
Forsmark 0–3	23.1	41.7	6.6	0.4	71.8
Kallrigafjärden 3–6	11.9	23.5	12.0	1.7	49.1
Forsmark 3–6	11.2	42.2	3.8	0.8	58.0
Kallrigafjärden 6–10	16.3	13.1	5.6	1.7	36.6
Forsmark 6–10	17.9	19.1	5.1	2.8	44.9

4.3.2 Hydroacoustics

Fish abundance, biomass, densities and species composition were investigated at Forsmark using hydroacoustics and trawling. The results are presented in /Axenroth and Hansson, 2005/. A summary of that report is given here (Table 4-6 and 4-7).

The studies were performed twice, in May and August/September 2004. The results from Forsmark were compared with two reference areas, NW Öregrund and NE Gudinge. The Forsmark area is influenced by cooling-water from the nuclear power plant at Forsmark. This area had higher fish abundance than Gudinge in May as well as in August/September 2004. The fish size distributions were similar in May but differed in August/September having more small, young-of-the-year, juvenile fish at Gudinge. Öregrund seems to differ from both Forsmark and Gudinge, which probably reflects general differences in depth, topography etc. The trawling results show that herring is the dominant species in these areas both in spring and late summer/early autumn. In spring sticklebacks are also common, and sprat and gobies in August–September. Calculations of total fish biomass in the Forsmark area gives about 40 kg/ha in late summer and 25 kg/ha in May. In the area close to Öregrund biomass was as high as 90 kg/ha, probably reflecting aggregations of spawning herring. Otherwise herring catches in parallel trawling showed dominance of young herring.

Table 4-6. Calculated fish biomass in May /from Axenrot and Hansson, 2005/.

	Forsmark	Öregrund	Gudinge
Mean s_A	91.2 ± 3.1	741.9 ± 25.6	50.1 ± 3.9
Area density (number/nautic mile^2 (millions; 2 m layers))	0.8	0.9	0.4
per m^2	0.2	0.3	0.1
per ha	2,408	2,738	1,210
per km^2	240,750	273,789	121,029
Biomass (kg/nmi^2)	8,683 ± 169	31,249 ± 1,884	1,788 ± 69
per m^2	0.003	0.009	0.001
per ha	25	91	5
per km^2	2,532	9,111	521

Table 4-7. Calculated biomass in August/September /from Axenrot and Hansson, 2005/.

	Forsmark	Öregrund	Gudinge
Mean s_A	161.2 ± 1.6	191.5 ± 2.1	136.1 ± 1.3
Area density (number/nmi^2 (millions; 2 m layers))	1.2	0.9	1.4
per m^2	0.3	0.3	0.4
per ha	3,455	2,699	3,940
per km^2	345,516	269,879	394,023
Biomass (kg/nmi^2)	14,164 ± 129	9,645 ± 75	8,235 ± 83
per m^2	0.004	0.003	0.002
per ha	41	28	24
per km^2	4,129	2,812	2,401

5 Discussion

In this paper we have presented a characterisation of the costal fish community at Forsmark and an attempt to estimate fish biomass in kg/ha for the area. The data will be used in an ecosystem model for the SKB Forsmark site investigation. Data available for the analysis comes mainly from the control program for the nuclear power plant. The area studied in that program is situated somewhat north of the site investigation area. Thus, a gillnet test-fishing was performed in the bay of Kallrigafjärden for comparison. Biomass was also calculated for young and small-sized pelagic fish by using hydroacoustics.

A calculation of abundances or biomasses per area, based on gill-net test fishing, gives highly uncertain values. In this report, we used data from the Biotest basin at Forsmark where abundance data was available from mark-recapture studies and parallel test-fishing's with the same kind of nets used outside the basin. Catches in gill-nets, however, not only reflect the number of fish in the area, which differs between years, habitats and seasons, but also the activity of the fish. The activity is in turn affected by several factors. We have calculated biomass/ha for the site area, but to understand the uncertainty of these estimates we analysed the factors influencing variations in these data.

Total biomass based on gill-net studies resulted in mean values at the Forsmark site between 60 and 70 kg/ha. The difference between the two study areas at Forsmark was small, which means that data from the control program area may be used in the present analyse. Studies of fish impinged on the intake side of the cooling-water system of the power-plant showed that pelagic small-sized and young fish of herring, sticklebacks, gobies and sprat dominated. These were also the fish that dominated in the hydroacoustics studies made at the same time in August as the test-fishing. The latter studies were used to calculate biomass for that group of fishes in Forsmark to be about 40 kg/ha. There is a dominance of young-of-the-year herring in that study. In May the corresponding value was 25 kg/ha. If there are spawning aggregations of adult fish, this value may increase considerably. This was demonstrated in a reference area close to Öregrund south of the Forsmark. In that area biomass was calculated to be 90 kg/ha.

Although the calculated data for biomass per hectare have considerable uncertainties, a comparison with literature data on perch and total biomass (Table 5-1) showed that they are not unrealistic. Thus, they are within the variation that the literature data show for the type of fish community studied.

The analysis of CPUE in the test-fishing's demonstrates that the calculated data on biomass per hectare must be used with considerable caution. The calculations represent the situation in August, except for the May study with hydroacoustics. Earlier studies presented by /Neuman, 1982/ demonstrate that there are considerable seasonal migrations of fish within the site area. He demonstrated that such migrations are caused by seasonal changes in temperature, which affect so called "warm-water" and "cold-water" species differently due to different temperature preferences. Young fish also have higher temperature optima than old and larger fish /Karås and Thoresson, 1992/. Changes also occur due to spawning migrations. These migrations may differ considerably between species /Saulamo and Neuman, 2002/.

The results from our analysis of CPUE in the gill-net studies are generally in accordance with those presented by /Neuman, 1982/. Thus, in August warm-water species as perch and roach decreased with depth and cold-water species as herring and whitefish increased. The larger fish increased with depth and warm-water species as perch and roach showed an increasing CPUE with temperatures at least up to 22°C. Cold-water species demonstrated negative trends and ruffe no trend.

Table 5-1. Perch density and biomass as well as total fish biomass and species number for 19 populations from the literature.

Locality	Method	Perch density (ind/ha)	Perch biomass (B)(Kg/ha)	Total fish biomass (B)(Kg/ha)	Numbers of species	Reference
Forsmark, Sweden	mark-recapture, age > 1+ (app 10 cm)	222				Thoresson (unpublished)
Gulf of Finland	scuba-diving	260–550				/Sumari, 1963/
Gulf of Finland	scuba-diving	200–4,900				/Bagge et al. 1975/
Linnonsalmi strait, Finland	scuba-diving	362–472	9.5			/Pursiainen, 1975/
Ponds, Finland	Poisoning	200–250	2.5–49.5			/Toivonen et al. 1964/
River Thames, England	mark-recapture	20–2,590				/Williams, 1965/
Slapton ley, England	mark-recapture, age > 1+ (app 10 cm)	378			6	/Craig, 1974/
Klicava reservoir,	mark-recapture, age > 1 (app 10 cm)				16	/Holcik and Pivnicka, 1972/
Czechoslovakia	1957	890	33.7	59.1	16	/Holcik and Pivnicka, 1972/
	1964	650	24.6	151.7	16	/Holcik and Pivnicka, 1972/
	1967	408	9.2	194.6	16	/Holcik and Pivnicka, 1972/
	1968	377	9.2	161.3	16	/Holcik and Pivnicka, 1972/
	1970	149	6.7	122.9	16	/Holcik and Pivnicka, 1972/
Lake Kiutajärvi, Finland	mark-recapture, age > 1+ (app 10 cm)	193	10.8		5	/Lind et al. 1974/
Lake Vitalampa, Sweden	mark-recapture, age > 1+ (app 10 cm)	522	16.6		1	/Nyberg, 1976/
Lake Botjärn, Sweden	mark-recapture, age > 1+ (app 10 cm)	1,018	16.4		2	/Nyberg, 1976/
Windermere, England	CPUE (catch per unit efort)				7	/Craig et al. 1979/
	North Basin (1941–1976)	125–3,230	11–113		7	/Craig et al. 1979/
	South Basin (1941–1976)	1,040–5,950	49–260		7	/Craig et al. 1979/
Lake Suomunjärvi, Finland	scuba-diving age > 2	312	18.9		6	/Viljanen and Holopainen, 1982/
Alinen Mustajärvi, Finland	mark-recapture, age > 1+ (app 8.5 cm)	2,700	37		2	/Rask and Arvola, 1985/
Horkkajärvi, Finland	mark-recapture, age > 1+ (app 8.5 cm)	1,240	21		1	/Rask and Arvola, 1985/
Katnosa, Norway	mark-recapture, age > 1+ (app 10 cm)	164			5	/Edvardsen, 1973/
Munksjöen	mark-recapture, age > 4 (app 12 cm)	336	9.5	24	5	/Linløkken and Holt Seeland, 1996/
Loch Sand	mark-recapture, age > 1+ (app 12 cm)	207	8.9		4	/Treasurer, 1993/
Loch Lower	mark-recapture, age > 1+ (app 12 cm)	16	4.7		4	/Treasurer, 1993/
Loch Loirston	mark-recapture, age > 1+ (app 12 cm)	1,226	30		4	/Treasurer, 1993/

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