Integrated fish monitoring in coastal reference areas. Ecological project.

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SUMMARY

”Integrated fish monitoring in coastal reference areas” consists of an ecological and a physiological/biochemical project following all organizational levels from cell to community, associated to a contaminant monitoring programme. This report treats the ecological project.

The main objectives are to:

1. Provide references for locally polluted areas.
2. Follow changes in the coastal ecosystems due to impact from land and the open sea.
3. Indicate large-scale changes in the seas surrounding Sweden due to natural processes, toxic substances, plant nutrients, global warming and resource exploitation. In many cases this can be done cheaper and more efficiently than in the open sea.
4. Follow the development of archipelagoes, due to their internationally unique character. Sweden has a special responsibility in this respect.

To fulfil the objectives, the investigations must be made in areas free from local human impact and representing important Swedish coastal systems. Basic studies for integrated monitoring have been running for three years in one Baltic and one Skagerrak archipelago. Besides this, ecological fish monitoring is carried out in eight other reference areas, four of them in Finland and Estonia.

The programme is directed towards demersal coastal fish communities. It is based on a stratified monitoring of abundance with gill and fyke nets minimizing variations within year and between stations. A view of the health condition is gained by checking external disease symptoms on every fish caught. Model species, stationary during all their life cycle, were selected for the combined physiological and ecological studies. Perch is studied at the east and viviparous blenny at the west coast.

For the model species, year-class size, mortality and growth are studied through age-analyses. Age at maturity, frequency of females with developing gonads, and relative weight of the gonad indicating reproductive capacity are recorded. The studies are made in combination with clinical health tests, also using biomarkers. The blenny offers special possibilities as it carries its fry in the ovary for 4—6 months after hatching. The number of fry and their growth and mortality are recorded. The physiological and biochemical analyses on perch provide a solid background for monitoring. In viviparous blenny, the results so far are promising, but some development is still required.

This report mainly presents the statistical variations of the test fishing results. The variations are reasonably low and the catches at different stations covariate closely between years. Trends at 3—5% per year can be detected in the common species.

For the future we suggest that a fish programme comprising ecological and physiological variables, including a biomarker approach, should be run together with contaminant analyses in four national reference areas.

BACKGROUND

The project ”Integrated fish monitoring in coastal reference areas” emanates from monitoring of water bodies receiving industrial waste water and cooling water from nuclear power plants. Systematic yearly measurements of fish species distributions, abundance, age distribution and growth were started by the Institute of Coastal Research in 1962. Parallell observations are made in areas free from local pollution, ”reference areas”, in order to cope with the great natural variations between years, which are typical for the Swedish coastal ecosystems. Ten national/international reference areas are now studied, nine of them in the Baltic within a Swedish-Finnish-Estonian cooperation (Fig. 1).

One of the main aims of the ”Swedish Environmental Monitoring Programme” (PMK) is to provide references for the monitoring of locally polluted waters. Generally this aim has not been fulfilled, and ecological monitoring of fish was completely left out in the original programme. The main reason was the opinion that the Fisheries Board should take the responsibility, which it did not do. When additional money was granted for a development of the PMK in 1989, however, reference studies on fish could be started in one area at the west and one at the east coast (Fjällbacka and Kvädöfjärden; Fig. 1). Mainly data gathered from these two areas in 1989—1991 are — of formal reasons — treated in this report. Some examples from older material will also be used, however.

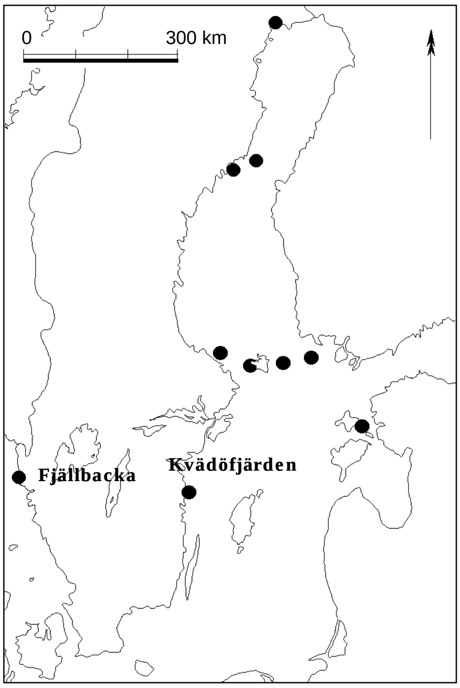

Figure 1. Reference areas.

During the 70’s and 80’s Swedish ecotoxicologists adapted laboratory methods for checking fish health to field use. Within the project Environment/Cellulose, a coordination was made with ecological studies resulting in the ”integrated fish monitoring” system, which is now also adopted in reference areas. The physiological and biochemical parts are treated in a separate report (Balk et al. 1992), but the variables in question are listed here too, and examples of results of the integrated programme are given in Annex 2.

There are both technical and political **arguments for** using **fish** in environmental monitoring. The technical ones can be summarized as follows:

Effect integration — Belonging to a high trophic level fishes react to processes at lower levels, where they might be difficult to discover due to, e.g., a short life span of the organisms. The long life of fishes enables an integration also over time.

Alarm function — Two million fishing Swedes observing fish kills, diseases and stock changes support the monitoring.

Bioconcentration — Bioconcentration and biomagnification of contaminants are more accentuated in fish than in other water-breathing animals.

Knowledge — The biological information on fish is much greater than that on other aquatic organisms. This is valid also for field and laboratory investigation techniques.

Size — Most fishes grow big enough to allow chemical and biological measurements to be made on single individuals.

The political reasons for monitoring fish can be summarized as the need to check the realization of the following, officially stipulated, ”environmental goals”:

1. Naturally occurring species shall be kept in vigorous, balanced populations.
2. Man and animals shall be able to consume fish and shellfish without any health risk.
3. A sustainable fishery shall be possible.
4. Pollutants shall not limit the possibilities to exploit the fish resources for recreational purposes.

The fish monitoring in reference areas have four **main objectives**:

1. Provide reference material for studies of areas under influence of local human activities. This is a mandatory task for PMK, as fish, especially monitoring of abundance, now has a central position in the recently established control programs for the most important coastal industries (pulp mills, nuclear power plants and metal industries).
2. Contribute to the general monitoring of the changes in the coastal ecosystems due to impact from land and the open sea. Moreover, the coastal zone is vital as nursery area for many open sea species, and at the same time the immediate receiver of our own pollutants.
3. Indicate large-scale changes in the seas surrounding Sweden due to natural processes or toxic substances, plant nutrients, global warming and resource exploitation. In many cases this can be done cheaper and more efficiently at the coast than in the open sea.
4. As the selected reference areas are situated in archipelagoes of an internationally unique character, we have a special responsibility to follow their development in biological monitoring.

PROGRAMME STRUCTURE

In the open sea and the pelagial of the coastal waters there are only migratory fish species. The stocks of these species can not be monitored in the coastal zone, where they occur occasionally, but must be based on the international stock assessments coordinated by the ICES. Information from this programme will be delivered to the Swedish Environmental Monitoring Programme by the National Board of Fisheries.

The monitoring of coastal fish gives priority to species spending all, or a great deal of, their life cycle in the coastal zone. The genuine coastal species are demersal, i.e., they live mainly **close to the bottom**. Linking the reactions of the fish to the environmental situation in a specific study area, presupposes a **stationary** behaviour all the life cycle, particularly with regard to measurements on the individual level. In addition, the system concentrates on **adults** of relatively **large** species because they allow individual chemical and biological analyses, are easy to catch with established methods and are of interest for fishermen and anglers.

The species monitored, i.e., demersal fairly large fish, can be grouped into two communities at the Baltic coasts: littoral, mainly stationary warm-water species, and often less stationary cold-water species living in deeper water. Migrating demersal species are also monitored as they by their high abundances are important as food for birds and mammals and as predators on other fishes. The most common fishes in the former group are perch and cyprinids, especially roach, whereas the latter mainly consists of flounder, cod, sculpins, viviparous blenny, and whitefish. At the west coast, cold-water species such as cod, flatfishes, viviparous blenny and sea scorpion dominate also in shallow water.

The basic part of the system consists of test fishings recording variations over time in abundance and species distribution, which give information on the net result of reproduction and survival. Early warning and support for interpretations of impaired reproduction and increased mortality are gained by observing sublethal disturbances on individuals of selected model species. In these are also followed concentrations of harmful substances; this program is described by Bignert et al. (1992). Consequently the integrated program shall give information on different levels of organisation from cell to community (Table 1).

The species most thoroughly tested in the Swedish integrated studies is the perch (*Perca fluviatilis* L.); it has been successfully used at, e.g., nuclear power plants, pulp mills and metal industries. It is used as model species for the east coast, but being a freshwater fish, it is not found at the west coast. There we use the viviparous blenny (*Zoarces viviparus* L.). We have not yet gained as much experience from this species as from perch, but the studies made so far are promising. As it is common also in the Baltic, we will introduce it as model species there, too. Besides a very stationary behaviour, the blenny gives birth to its fry after a long gestation period (4—6 months). Thanks to this, a general problem is eliminated in studies of reproduction parameters in fish, namely the difficulty to identify brood origin and measure reproduction success among individuals. Survival and growth of the fry can be studied and as dead fry are preserved in the female, also mortality in different stages can be established. More information on perch and blenny as indicator species is given in Annex 2 and in Balk et al. (1992).

Table 1. Integrated fish monitoring.

Level of organisation	*Parameters*	*Processes measured or indicated*
Community	Species composition	Species interactions
Population	Catch per effort Age distribution	Recruitment and mortality
Individual	Lenght increment per year	Growth
	Gonad weight	Reproduction
	Fecundity	Reproduction
	Weight/length relation	Energy storage
Tissue/organ	Occurrence of diseases	Mortality
	Plasma ions	Mortality
	Plasma glucose and lactic acid	Metabolism
	Liver size	Toxicant processing
	Liver enzyme activity	Toxicant processing
	Conc. of toxicants	Toxicant uptake
Cell	Red blood cell count	Mortality
	Haemoglobine	Mortality
	White blood cell count	Mortality

The integrated studies on perch and blenny mainly are designed to indicate effects of toxic substances, whereas eutrophication principally is reflected in species composition and abundance. Among our common coastal fishes, the roach reacts most clearly on eutrophication. For this species the monitoring of abundance therefore is supplemented by studies of growth and recruitment.

Technically, the programme consists of two main parts: population studies and analyses on individuals. Besides these, supporting hydrographic measurements are made. The ecological methods are described in detail by Thoresson (1992) and the biochemical and physiological in Balk et al.(1992). A short description and some comments are given below.

Population analyses

Variations in the abundance of demersal fish

As the programme is concentrated to demersal fish, traditional fishing methods are preferred to monitor variations in abundance. Hydroacustic methods are not efficient close to the bottom, and counting of fish by Scuba divers is too time consuming and too dependent on the capacity of the diver. Different kinds of drop-nets as well as such traditional gears as trawls and seines cannot be used on the rough and uneven bottoms typical for our archipelagoes. Moreover, operating these kinds of active gears often is so time consuming, that the number of statistical observations tends to be too low. Consequently, we have chosen passive gear, i.e. gill nets and fyke nets.

Gill and fyke nets are cheap and easy to handle, which admits the use of a high number giving many statistical observations. Their most important disadvantage is that the catches are dependent on variations in locomotor activity. The statistical layout, however, handles the daily variations, and significant long-term activity changes are hard to imagine. Another problem is the size selectivity of gill nets. However, by directing the fishing towards mainly adults of relatively large species, it is possible to monitor long-term changes fairly precisely with a few mesh-sizes (4 or 5).

The design of the test fishing, as in all other monitoring of inter-year variations in biological processes, places strict demands on statistical planning. The methods used have been developed through many years of pilot studies and statistical tests. By means of stratification as regards species and size groups, depth intervals, exposure and time of the year, it has been possible to create statistically satisfactory programmes at reasonable expenses. The layout is described below.

Area	*Shallow 2—5 m*	*Period*	*Deep 14—20 m*	*Period*
The Baltic	Gill nets	August	Gill nets	October
The west coast	Fyke nets	October	Gill nets	October

In each depth interval there are several stations, which are fished several times. The number of fishes caught are registered to species, length group and station, and the results are expressed as number per station and night. For pregnant blennies also the number of fry and their growth and mortality are recorded.

<u>Age composition</u>

To follow variations in recruitment, and in adult mortality, the age composition is monitored in perch, viviparous blenny and roach by analyzing annuli in bony tissues. The age composition of the sampled fish (ca 300) can be transferred to the whole catch as the fishes are recorded in length groups.

Analyses of individuals

Studies of individuals are presented under the headings ”reproduction”, ”growth” and ”health condition”. The experience shows that, compared with other integrated functions, the reproduction is very sensitive to toxic substances. The growth rate is a measure of the energy status of the fish but may also indicate eutrophication. The purpose of studies of health condition is to gain early warning of increased mortality or disturbed reproduction before these effects can be seen at the population level. If the population monitoring indicates disturbances on other species than the indicator species, individual studies of these other species will also be made.

<u>Reproduction</u>

Fecundity, i.e., the number of eggs per female, is an important population dynamics parameter. Both pollution and feed availability may influence the reproduction capacity of the fish. Measuring fecundity is very labourious and thus the gonad size (gonad weight / body length) is monitored as a rough estimate. If this variable indicates disturbances, fecundity will be measured, however. In addition to studies of gonad weight, controls are also made of the occurrence of such fishes which will not spawn in the subsequent spawning period. The reproductive success of the blenny is studied by recording the number and size of the fry.

Growth

Growth studies are essential when estimating changes in production. Growth rate can also be utilized as an indication of health condition and reflects variations in consumtion. As indicator, it has the advantage of integrating at a high level but the disadvantage of being exposed to large variations between years and individuals. Perch, viviparous blenny and roach are studied using annuli in bony tissues. Perch and roach admit back-calculation of growth. The growth of blenny fry is measured directly from their length.

Health condition

A rough view of the health condition of all species is gained by checking external disease symptoms on every fish caught. Open wounds, sceletal deformities, tumours, fin damages or other symptoms easy to diagnose are registered in accordance with the ICES-norm. Physiological and biochemical investigations are made on perch and blenny (Fig. 2 and Balk et al. 1992).

Couplings to other programmes

A basic principle of the PMK is that each programme independently shall give robust information on environmental changes, thus avoiding chain reactions, if one program fails. It is also important that each programme is sited where it has optimal conditions for trend monitoring. Of course, however, couplings to other programs facilitating interpretations are an advantage. The fish programme in itself is a coupled, integrated system, but it also has close couplings to monitoring of top predators, contaminants and hydrography. The relations to other programmes are treated further in Annex 3.

The time aspect

The sampling is done each year during two, maximally three, weeks. This period is short enough to allow the assumption that the stock size is constant and effects of growth and mortality negligable. The fishing is repeated six times at each station. At each time the nets are exposed 16 — 18 hours, thus catching both day and night active species. It is assumed that the probability of catching an arbitrary single fish at a certain station is the same for all days within the sampling period. The statistical population is not considered the same as the biological one, which comprises all fishes in the area. In the way we treat the data, the population is supposed to be generated from the number of fish per station.

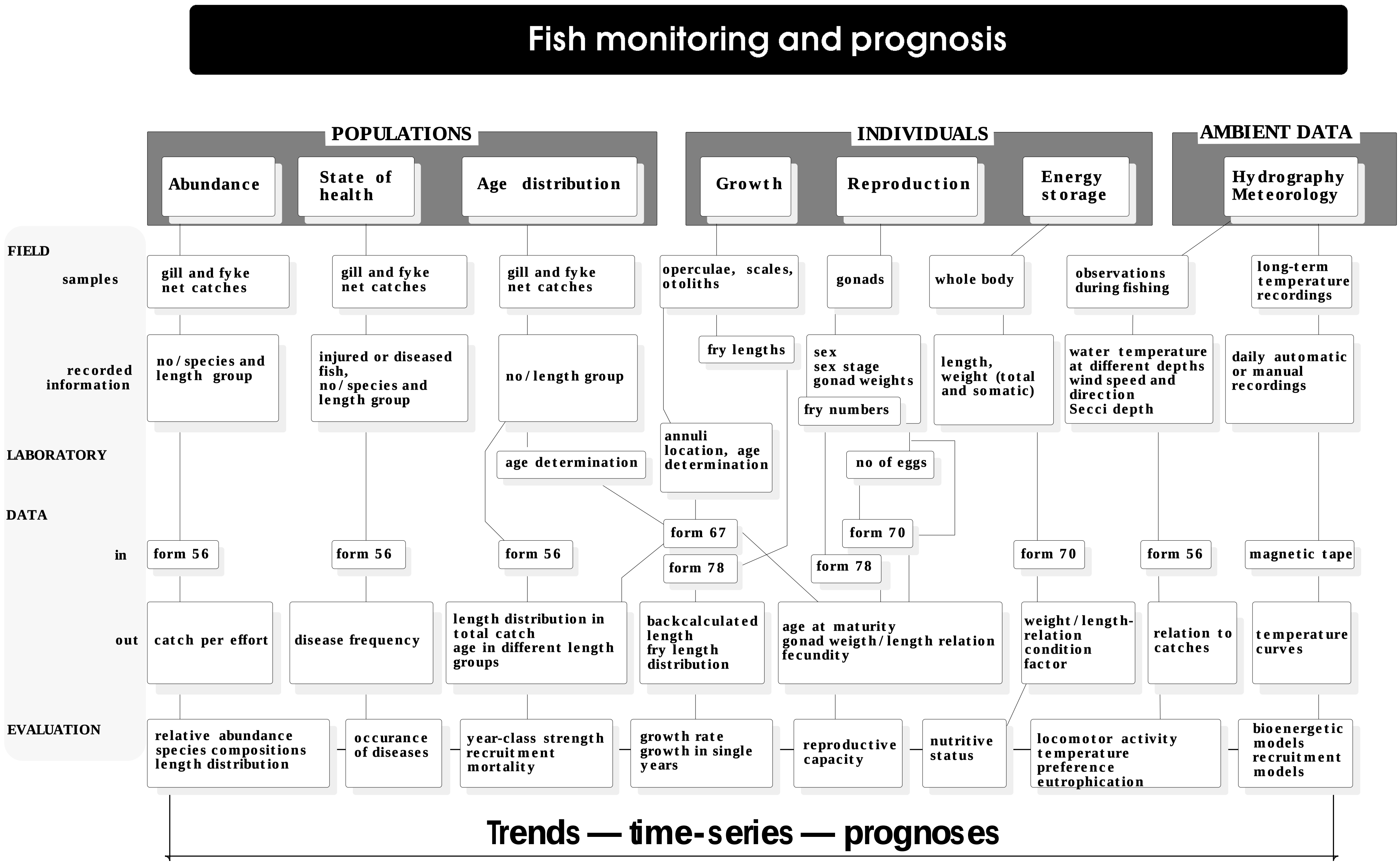

Figure 2. Fish monitoring and prognosis.

One of the main aims of the test fishing is to estimate the relative abun-dance of fish in a control area compared to a reference. After almost 20 years of monitoring, an analysis was performed in 1980 aiming to find the most appropriate period to follow the changes in abundance of coastal species. During the five months (May—October) that had been studied, we tried to define a short period for the future sampling. This evaluation had to consider several aspects as, e.g, a reasonably high mean level of catches, small variations in both time and space, and a high correlation to the other months. The calculations led to the choice of the beginning of August for the sampling of warmwater species and October for coldwater species. Thus, these periods are not chosen to represent the mean catch level of all the year but to be statistically optimal for monitoring changes in abundance between years.

The sampling periods are hydrographically stable, which means that extreme events are rare. If such events in other seasons affect, e.g., mortality and growth, this is recorded in the system.

The space aspect

The total integrated program is established only in one area in the Baltic proper, Kvädöfjärden, and one at the west coast, Fjällbacka (Fig. 1). The ecological part is running in another Baltic area in Estonia, and in four other areas in the Gulf of Bothnia, including Finnish areas. Three additio-nal Bothnian areas are now under evaluation (Fig. 1). This means that **all** coastal regions, where it is possible to place a reference area fulfilling the demands stated below, are, or will be, represented.

The areas are chosen in order to **represent** important archipelagoes and to give **background** values. Besides representativity and absence of local human impact, the most important criterion is the existence of **stationary fish** populations. Our reference areas and the criteria for them are treated further in Annex 1.

In the **representative areas**, **fixed** fishing **stations optimal for monitoring changes** in abundances are selected. They are placed in narrow strata representing preferred habitats thus ensuring a **rather high abundance** of fish. The strata are defined mainly according to depth. In each depth stratum (see above) there are normally two groups of stations, **sections**, representing different habitats as regards, e.g., exposure and bottom type. As it must be possible to treat the catches at different stations as **independent**, the stations must not affect each other and thus must not be placed too close to each other. For the final design a lot of stations are tested and those with the **smallest variations** between catches in time and space will be selected. Such a selection procedure will ensure a rather **low patchiness.**

At each station there are set two fyke nets or one gill net of each mesh-size used (4 or 5). The number of stations per section are at least 6 for gill nets and maximally 18 for fyke nets. The minimum number of stations has been decided after studies in several areas, which have shown that 6 is an acceptable minimum for our statistical treatment. The location of the stations in Kvädöfjärden are shown as an example in Fig. 3.

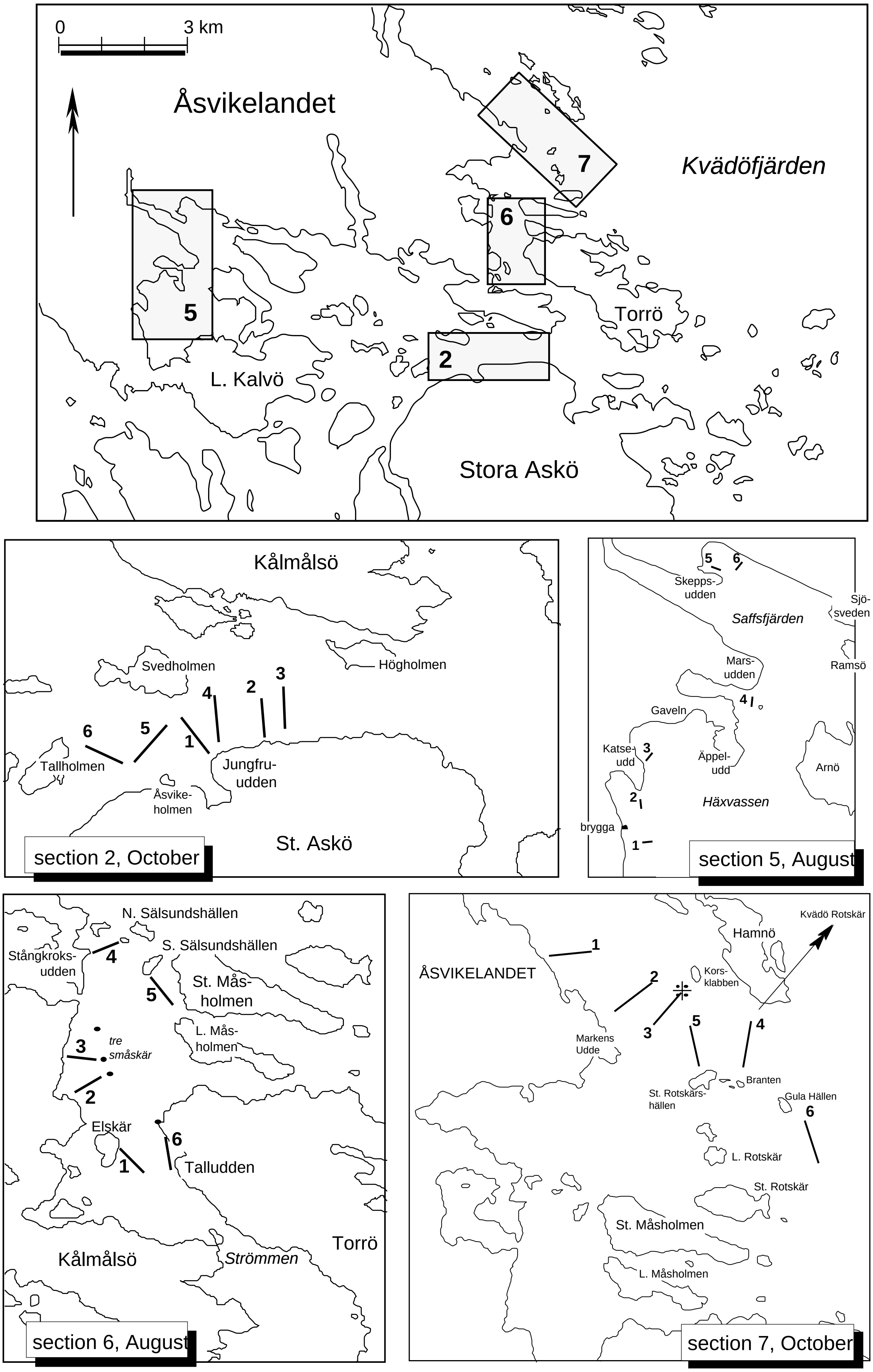

Figure 3. Fishing stations in Kvädöfjärden.

TREATMENT OF DATA

We have concentrated the discussion of data to catches, as they present the most interesting statistical problems and constitute the basis of our system. Some information on blenny fry will be given too, while we have left out year-class and growth analyses as we consider the statistics to be trivial.

For every species the catch at **one station one year** constitutes **an observation,** which is a mean of six days fishing. We assume, referring to above, that the observations are **independent**. **Arithmetical means** are used since the nonparametric Kolmogorov- Smirnov godness-of-fit test in most cases does not contradict the hypothesis of the frequency distribution being normally distributed. Only in a few cases geometric means could be preferred regarding skewness and K-S test. Logarithmic transformation often stabilizes the variance if the frequency distribution is skewed, but may give severe bias if the underlying distribution is not log-normal.

Table 2. Annual mean catches from Kvädöfjärden and Fjällbacka. Number of stations (n), arithmetical means (number/station and night), standard deviations (sd), coefficient of variation (cv) and 95% confidence intervals (95% c.i.) for some common species.

Perch (Kvädöfjärden)

year	n	mean	sd.	cv.	95 % c.i.
87	6	8.72	4.98	57	3.00 — 14.45
88	6	10.53	3.77	36	6.19 — 14.86
89	6	9.03	2.52	28	6.13 — 11.92
90	6	17.64	11.93	68	3.92 — 31.36
91	6	25.00	6.29	25	17.77 — 32.23

Roach (Kvädöfjärden)

year	n	mean	sd.	cv.	95 % c.i.
87	6	46.89	20.92	45	22.84 —70.94
88	6	35.58	12.41	35	21.32 —49.85
89	6	29.03	15.91	55	10.74 —47.32
90	6	46.28	28.99	63	12.95 —79.61
91	6	31.47	11.09	35	18.72 —44.22

Flounder (Kvädöfjärden)

year	n	mean	sd.	cv.	95 % c.i.
89	6	7.53	1.72	23	5.54 — 9.51
90	6	3.84	1.34	35	2.30 — 5.37
91	6	1.45	.52	36	.84 — 2.05

Fourhorned sculpin (Kvädöfjärden)

year	n	mean	sd.	cv.	95 % c.i.
89	6	21.31	5.26	25	15.26 —27.35
90	6	31.61	5.78	18	24.96 —38.26
91	6	2.78	.80	29	1.85 — 3.70

Ruffe (Kvädöfjärden)

year	n	mean	sd.	cv.	95 % c.i.
89	6	6.03	2.14	35	4.16 — 7.89
90	6	3.42	.94	27	2.33 — 4.50
91	6	13.58	5.30	39	7.49 —19.68

Viviparous blenny (Fjällbacka)

year	n	mean	sd.	cv.	95 % c.i.
89	15	2.13	1.10	52	1.62 — 2.99
90	15	3.69	1.34	36	3.04 — 4.72
91	15	.40	.41	103	.14 — .44

Standard deviations, coefficients of variation and 95% confidence intervals for the annual **arithmetical means** of catch per effort are shown in Table 2. For the Baltic area, we present August material from one section, where the monitoring started already in 1987, two years before the project under evaluation. The dominant species, perch and roach, comprise 70% of the total catch. In October, flounder, fourhorned sculpin and ruffe amount to nearly 80% of the total catch. The species of main interest at the west coast is viviparous blenny. Its share of the catch is 20% in the presented section. Plots of **time-series** for the most common species are presented in Fig. 4a—c and the **spatial variation** is shown in Fig. 5a—b. Annual means are shown as line plots.

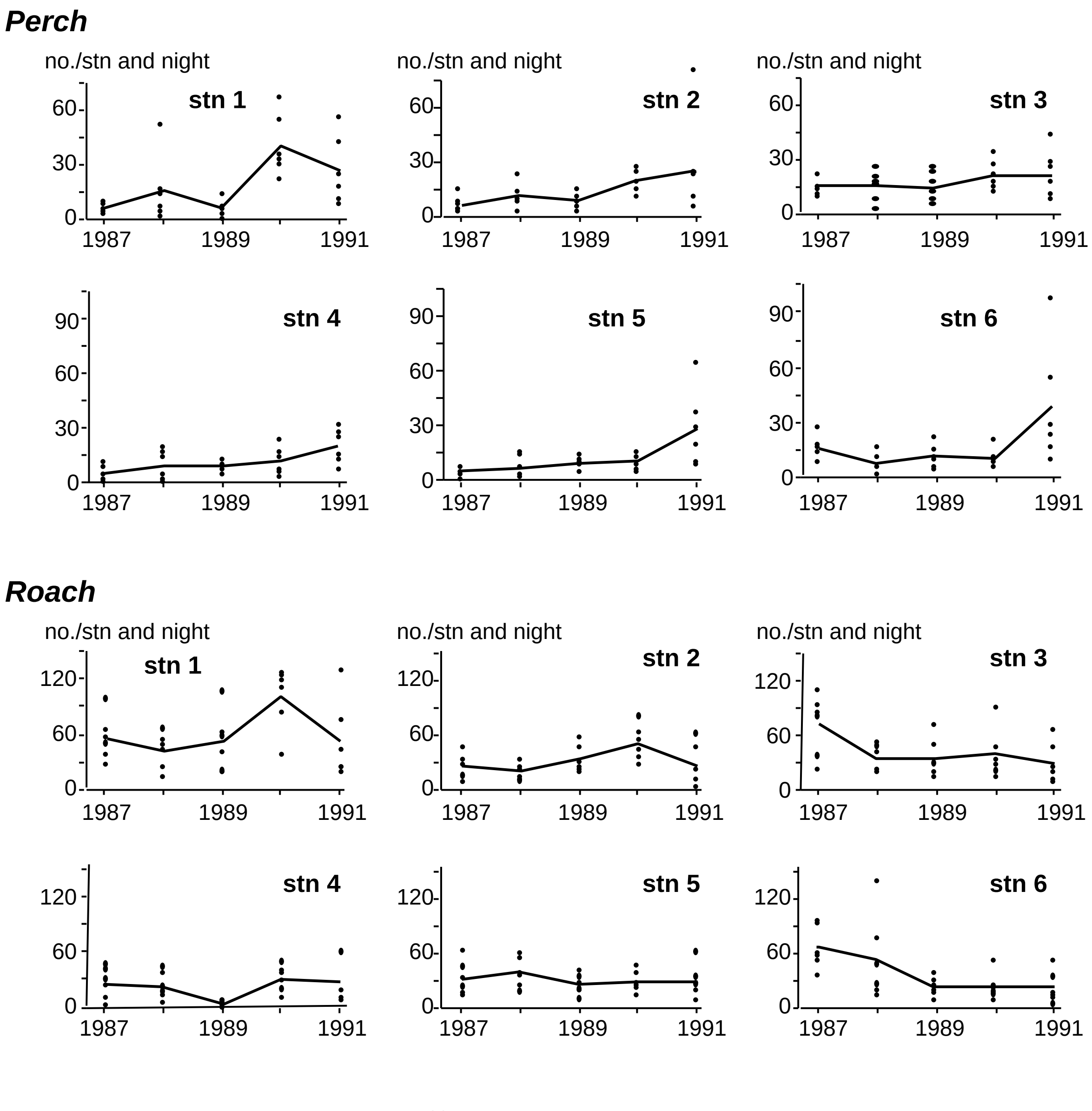

Figure 4a. Time series at different stations. Black dots indicate catch/ effort during different days.

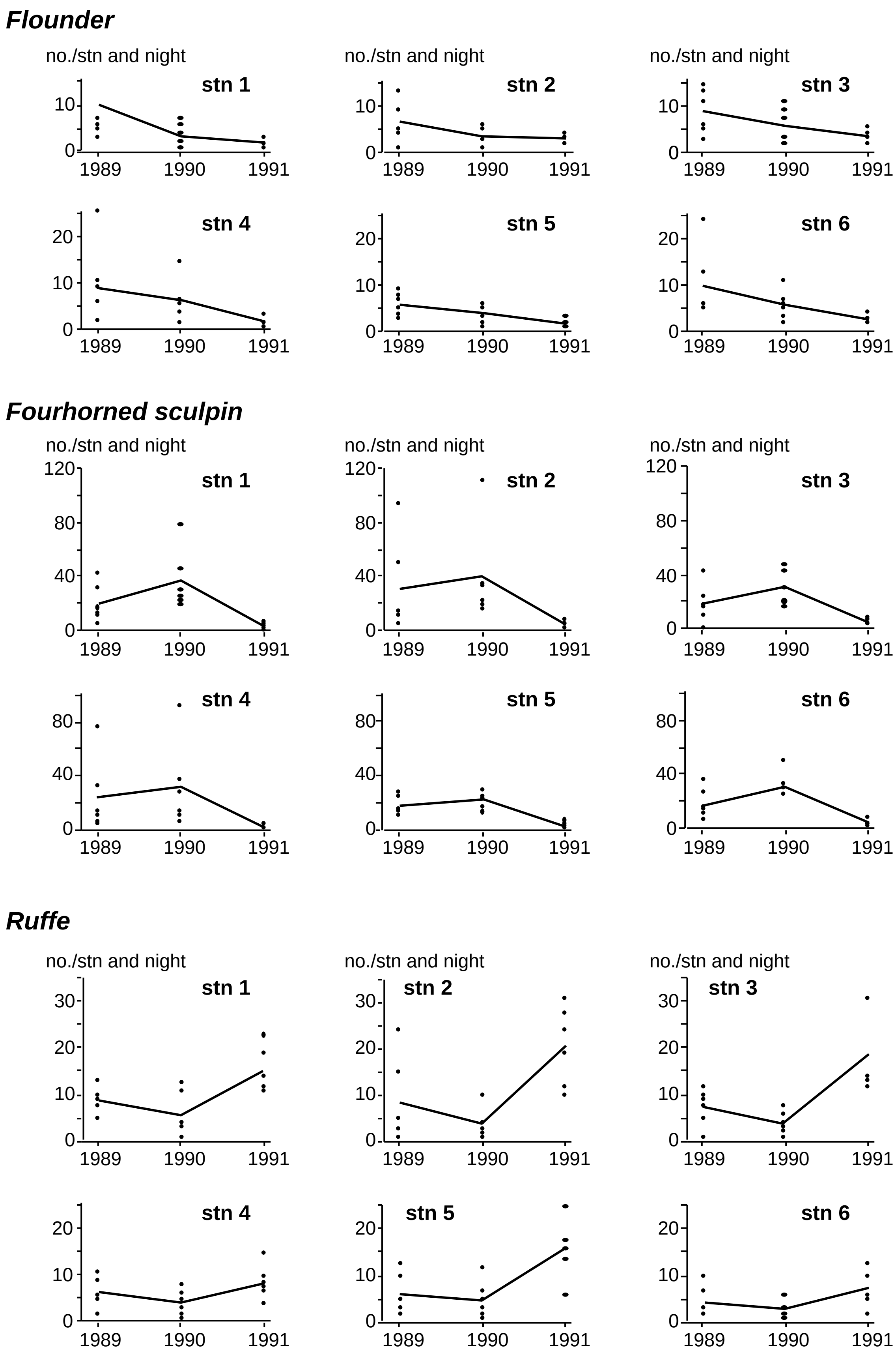

Figure 4b. Time series at different stations. Black dots indicate catch/ effort during different days.

Viviparous blenny

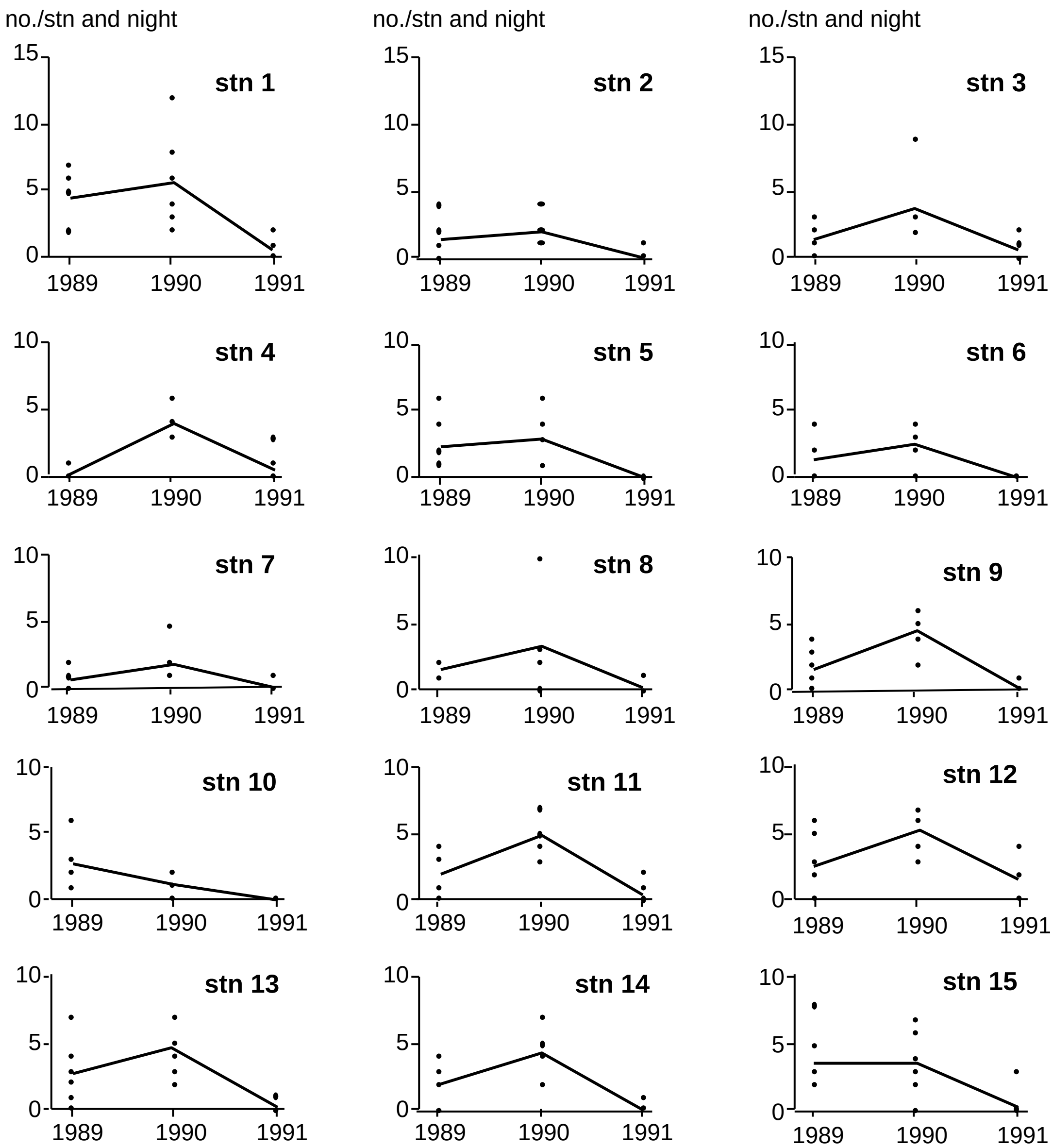

Figure 4c. Time series at different stations. Black dots indicate catch/ effort during different days.

Both parametric and nonparametric methods have been used in analysing trends and making model prognoses. A nonparametric technique that has been used for detecting monotonic trends is the Mann-Kendall test (Gilbert, 1987). The test can be viewed as a nonparametric test for zero slope of linear regression of time-ordered data versus time. The trend for each individual station is first calculated with the Mann-Kendall method. In this analysis every single observation (catch/night and station) is included. A chi-square test to check for homogeneity between the different stations is then carried out. If there is a nonsignificant result in this step, it is tested that the (common) trend direction is significantly different from zero, also with a chi-squares test.

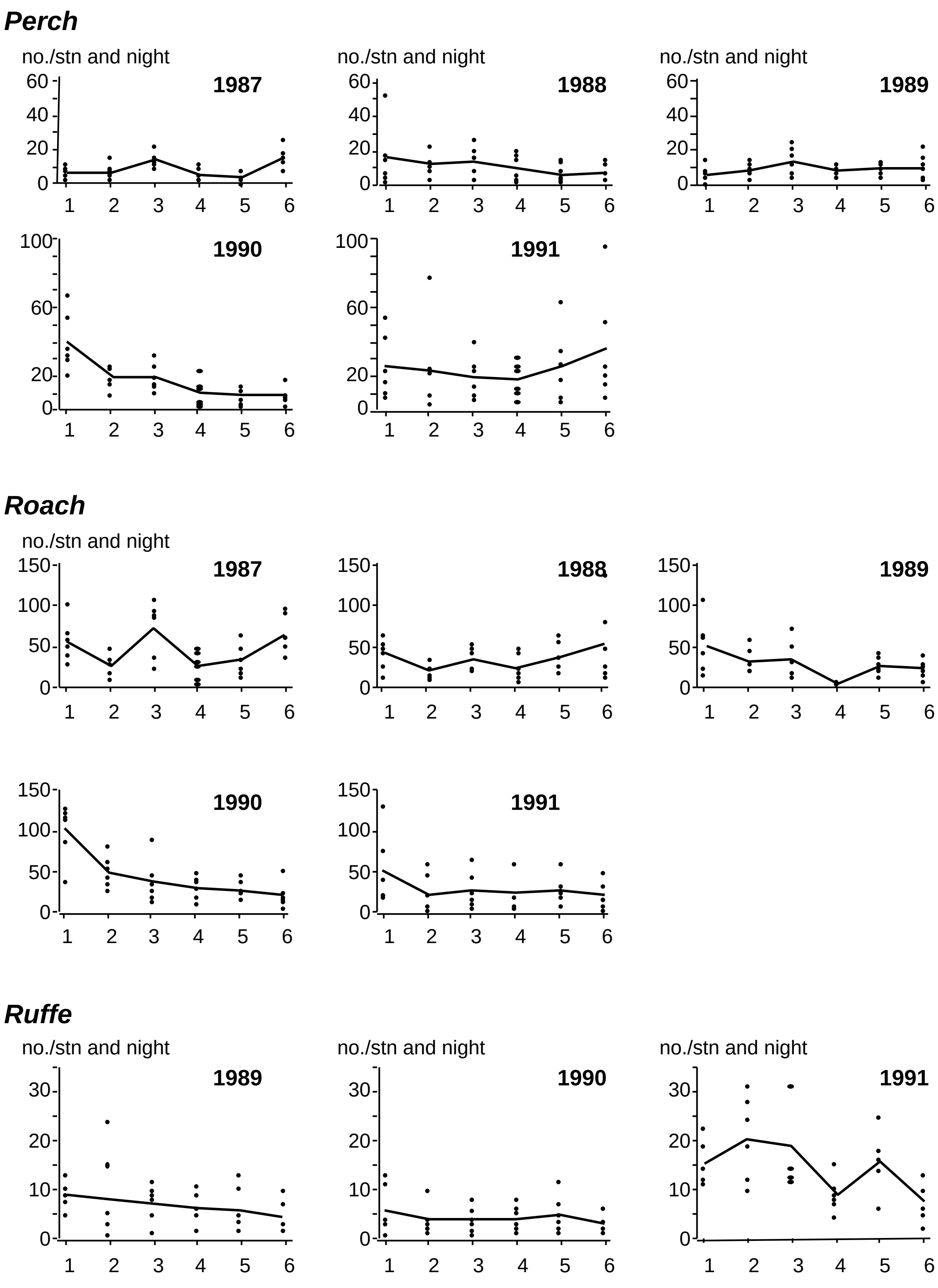

Figure 5a. Spatial variations in different years. Black dots indicate catch/ effort during different days.

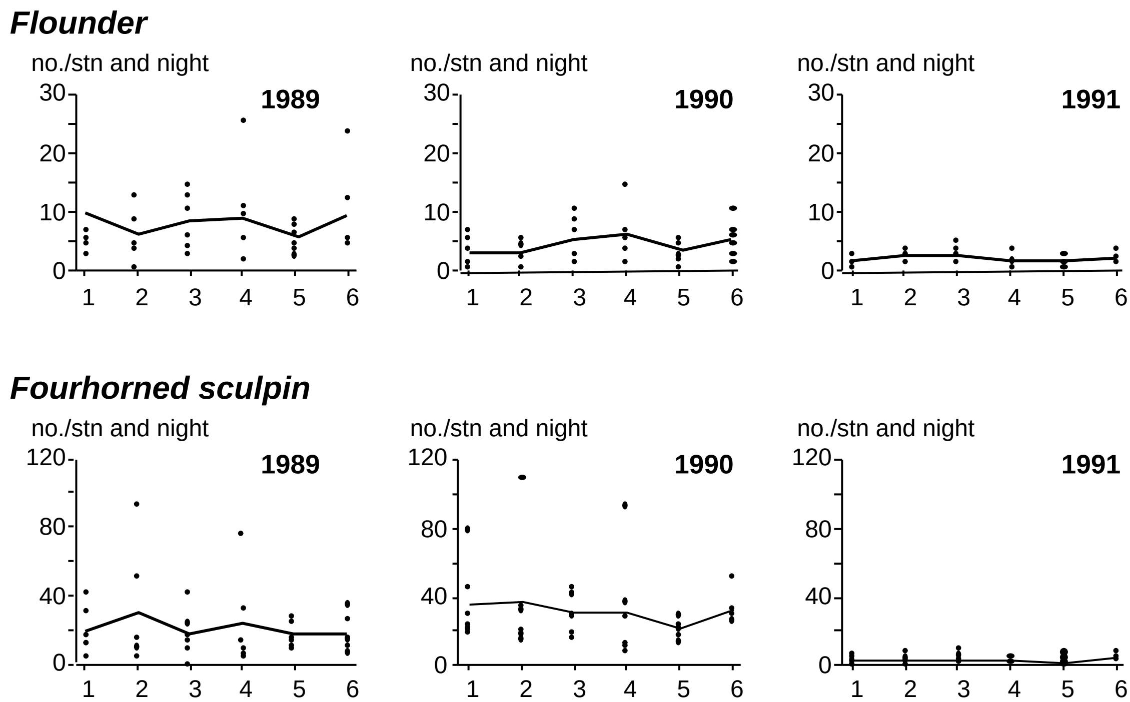

Figure 5b. Spatial variations in different years. Black dots indicate catch/ effort during different days.

Due to the short period in our example it is not meaningful to evaluate real trends, but merely to show the principles. The z-values on Mann Kendall's test statistic for perch, roach, flounder, fourhorned sculpin and ruffe are shown in Table 3. For all these species except roach, there is quite a strong homogeneity between the stations and a significant 'trend' is demonstrated. By this technique the within-year variation between stations will be eliminated while the test gives separate trends for each station and the chi-square test is expressing the homogeneity in these trends.

Table 3. Z-values of the Mann-Kendall test statistic for different species and chi-squares test showing trend and homogeneity in the catch/effort data of Kvädöfjärden 1987—1991.

	Species				
Station	Perch	Roach	Flounder	Fourhorned sculpin	Ruffe
1	2.9	0.7	–2.6	–2.1	.8
2	2.4	0.9	–2.0	–2.2	2.1
3	1.1	–2.3	–2.3	–1.6	2.1
4	2.5	0.2	–2.5	–2.6	1.0
5	3.2	–0.5	–3.0	–2.5	2.4
6	0.8	–3.3	–2.8	–1.9	1.0
Chi-square for homogeneity	4.78 ns	14.54 s	.67 ns	.61 ns	1.74 ns
Chi-square for common trend	27.7 s	2.87 ns	38.9 s	27.4 s	17.5 s

Chi-square (0.975;5)=12.83
s = significant
ns = nonsignificant

Another way of assessing a trend is by computing regressions for each station, average the slopes, and simply use standard methods for estimating the confidence limits of the mean slope. Perch shows a significant trend (Table 4). Here we assume that the b-values are independent observations of a t-distribution with n–1 stations as degrees of freedom. From general calculations assuming t-distributed variables it is possible to assess the necessary number of observations to detect changes with a given level of significance. In our case with perch we can detect a difference of 53% in trend between two areas, or between two periods of time, if using 6 stations. This means 9% per year for a five year period or correspondingly 4% for a ten year period. If we increase or reduce the number of observations with 50%, the corresponding detection limits will be 40 and 106%. Due to the small variances (Table 2) for the coldwater species it seems reasonable to believe that the possibility to detect trends will be at least as good as for perch.

Table 4. Means of the slopes (with 95 % c.i.) from different stations calculated with regression analysis.

	year	*no.*	*slope*	*95% c.i.*
Perch	87—91	6	3.96	2.24 — 5.68
Roach	87—91	6	–2.02	–9.68 — 4.26

Calculated according to Sen's method (median slope)

	year	*no.*	*slope*	*95% c.i.*
Perch	87—91	6	3.27	1.00 — 5.54
Roach	87—91	6	–2.21	–8.08 — 3.66

If we assume the 12 stations of the two different sections in Kvädöfjärden to give independent observations, the limit to detect a difference will be at 35%. Thus for a 10-year period the smallest change that can be verified will be 3% a year. The slope with Sen's nonparametric method (Sen 1968) gives a similar result.

A method of assessing power to detect linear trends in monitoring programmes has been developed within the ICES (Fryer & Nicholson 1990, 1991, Nicholsen & Fryer 1990). Table 5 and Fig. 6 show one example of this technique used for perch 1987—1991 with different scenarios. In this case it will take 11 years to detect a difference of 5% per year.

Table 5. Power of test for linear trend which is computed using regression with a locally-weighted running line smoother's technique.

Perch data (see table 2)

Period	*r.v.*	*ye*	*inc*	*s.l*	*P*	*Remarks*
87—91	0.0264	5	25	5	80	actual material
-"-	-"-	11	5	5	80	simulated
-"-	-"-	20	2	5	80	-"-

r.v.= the residual variance in the regression
ye = the smallest number of years to detect a trend
inc = the smallest increase to be detected (%).
s.l = level of significance (%)
P = power of the test (%) .

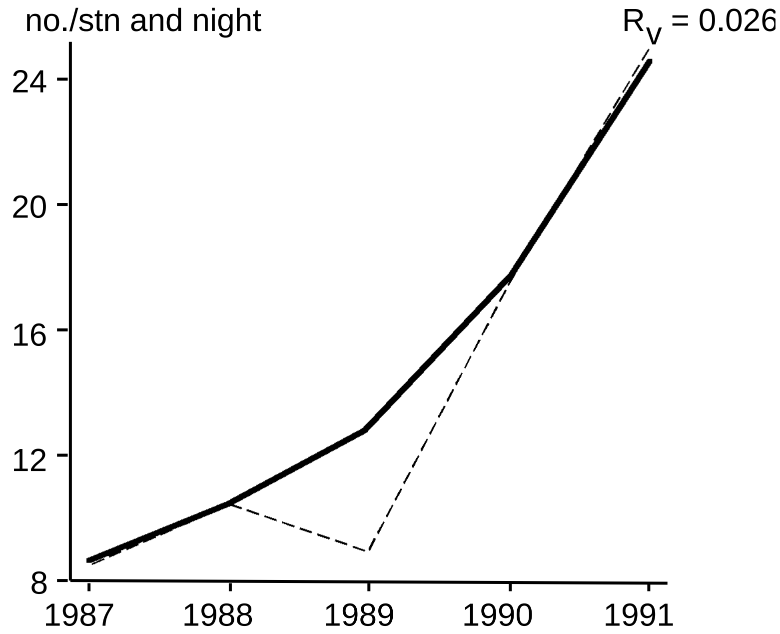

Figure 6. Trend in perch catches. Solid line shows a regression with a locally-weighted running line smoother's technique. Dotted line shows annual mean values. R_v *= residual variance.*

The number of fry hatched in the mother, their mortality at different stages and their growth are monitored in the viviparous blenny. At Fjällbacka, at least 50 ”pregnant” females are sampled per year. Living and dead fry are counted and classified in length groups of 2.5 mm. In 1989 and 1990 the size was only classified in ”small” and ”normal” and the total weight of fry was recorded. The number of fry in relation to the size of the female gives information on the reproductive capacity. As neither the mean size of the females nor the mean number of fry per female changed between 1989 and 1990, it can be concluded that the reproductive capacity was stable (Table 6). So were the mean weight of fry, the share of small fry and the frequency distribution of small fry per female.

For 1989 the percentage of females with small fry are compared (Table 7) between Fjällbacka and some areas under influence of environmental disturbances in order to test the sensitivity of this parameter. In two of them, the share of such females was significantly higher than at Fjällbacka. In these two areas, also several fry had died in a late stage of the development. This must be considered to be a very strong indication of disturbance, as not a single fry of this category has been found in areas without local impact. In one of these polluted areas, it was possible to find statistical differences between stations at different distances from the waste water discharges (Annex 2).

Table 6. Data on the viviparous blenny from Fjällbacka 1989 and 1990.

Female

	no.	*mean length (mm)*	*sd.*	*cv.*	
1989	95	23.8	2.50	11	ND
1990	59	23.3	3.00	13	ND

Fry

	no.	*mean number per female*	*sd.*	*cv.*
1989	95	41.4	20.8	50
1990	59	42.7	22.3	52

	no.	*mean weight per female*	*sd.*	*cv.*
1989	95	0.20	0.06	30
1990	59	0.20	0.05	25

	% small of total number of fry		*% females with small fry of total number of females*	
	total	*%*	*no.*	*%*
1989	4200	0.7	95	26
1990	2507	0.9	59	25

Frequency distribution of small fry per female

	0—2	*2—4*	*4—6*	*6—8*	*8—10*	*>10*	*%*
1989	82	12	4	1	0	1	%
1990	80	10	2	7	2	0	%

no. = number of females
sd = standard deviation
cv = coefficient of variation
ND = normally distributed

Table 7. Females carrying small fry as percent of the total number of females in the 1989 material.

	no.	*% females*	
Fjällbacka	95	26	
Idefjorden	46	52+	pulp mill
Brofjorden	40	25	oil refinery
Stenungsund	14	57+	petrochemical industries
Göteborg	150	21	urban area

+ significantly different from Fjällbacka

Errors

The catching capacity of a net might be reduced by disturbances, e.g. storms, which might cause strong currents and drift of vegetation. In the chosen sampling seasons, this is no big problem; less than 1% of the catches are significantly affected. The disturbances are registered and the nets in question could be eliminated from the calculations. During the sampling seasons, there is a minor risk to catch so much fish, that the catch efficiency is significantly reduced.

There is no risk to make errors in the identification of species and the risk to overlook some individual in recording the catch is insignificant. A fish with a length close to the limit between two length-groups (2.5 cm) can be assigned to the wrong one. The consequence of this is not great, however, and such mistakes tend to compensate each others.

Among the analyses of individuals, the age and growth analyses are most subjected to errors. 3—5% of the samples have so undistinct annuli, that they have to be discarded. This tends to give a slight underrepresentation of slow-growing and old individuals.

METHODS

No changes of methods have been made during the pilot project.

QUALITY ASSURANCE

Both field and laboratory work follow strict, well documented routines, and there are detailed specifications on the fishing gear (Thoresson 1992). It is stressed that the position of the stations must be carefully documented. The **catch data** are evaluated by checking data lists within a short time after the fishing. The checking is done both by those responsible for the field work and by an ADB-specialist. Obvious mistakes and unrealistic observations on species, number and length-group are changed after contacts with the field worker.

To test the **age** and **growth analyses**, 10% of the analyses are made by two experienced persons independently. Moreover, there is an evaluation programme checking if growth and length at different ages are realistic.

ORGANIZATION

The programme is run by the Institute of Coastal Research, which is one of three institutes within the National Board of Fisheries. Besides administrative personell, nine persons at the institute are partly engaged in the programme together with four fishermen. The head of the institute is project leader and evaluates the results together with one specialist in recruitment, one in biomarker systems, and one statistician. The data are processed by an ADB-specialist. The laboratory work is made by two specialists in age analysis, and one biologist is responsible for the field work in each area. The necessary practical resources — nets, boats, equipment for age analysis, computers and a large program library — are available.

The work is coordinated with fish monitoring in reference areas in Finland and Estonia, which involves several qualified biologists from these countries in the program. The coordination was ensured by employing a coordinator placed at Åland. We cooperate with the physiologists working in the integrated program by frequent, informal contacts concerning field work and evaluation of results and more formally in an ”integration group” for the Swedish reference areas meeting annually. Scientists carrying out the national monitoring of contaminants are also included in this group. In

Kvädöfjärden and two other reference areas there is a coupling to monitoring of soft bottom fauna made by our institute. Finally, the possibilities for a coordination with the top predator programmes are now under discussion.

QUALIFICATIONS OF THE PERSONELL

Applications of the methods used in the project have been the main task for all persons engaged for eleven to thirty years. Three doctors in zoology and two candidates (B.Sc) — one zoologist and one statistician — work in the project. Among the others engaged, three have special education in fishery biology, ADB and laboratory techniques respectively.

REPORTING ROUTINES

Annual reports following strict formal routines are sent to the principal, the Swedish Environmental Protection Agency. As the project has a pilot character, copies are sent only to a small number of colleagues. Established programs are reported, in most cases anually, to the agency mentioned, to the National Board of Fisheries, to county and town administrations as well as industries concerned, and to colleagues in Sweden, Finland and Estonia.

RESULTS

The aim of the project under evaluation has been to test and improve the integrated programme for use in PMK. We consider this fulfilled and find the programme ready to expand to other reference areas.

Our older studies in reference areas, which started in 1962, have yielded several results, some of them treated in Annexes 2 and 3. They constitute the only long-term monitoring of abundance of coastal fishes in Sweden and, consequently, they have produced new basic information on the dynamics of the stocks in question.

Our reference system has been necessary for identifying effects of several coastal industries, mainly nuclear power plants and pulp mills (Annex 2). The most important result of the site-monitoring is the elucidation of the impact of pulp mills on fish, which has been the main cause for the current radical restrictions of the emisssions from not only Swedish but also Finnish and North American mills.

We use data from the reference areas in analyses of variations in time and space; the solution of most ecological problems in the very varying Swedish coastal systems needs long-term data. The development of the integrated fish monitoring includes advanced research and contacts with other disciplines: physiologists, pathologists and chemists. Generally speaking, data from the reference areas play an important role in nearly all research carried out in or institute.

FUTURE PROGRAMME

We suggest fish monitoring within a national programme in four reference areas fulfilling strict criteria: Holmöarna in the Northern Quark, Finbo in NW Åland, Kvädöfjärden and Fjällbacka. Thanks to our coastal surveys we can suggest up to eight more regional sampling areas, five at the east and three at the west coast, thus improving the geographical representation and strengthening the possibilities to detect deviations at local impact sites. We are convinced that studies in polluted areas also will lead to the development of new biomarkers, especially directed towards reproduction. When such methods are established in the local monitoring, they will also be introduced in the national programme.

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