Spatial and temporal representativeness of water monitoring efforts in the Baltic Sea coast of SW Finland

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Traditional *in situ* surface water sampling produces accurate information on water chemistry and biology. Such sampling is conducted primarily as part of water quality monitoring programmes. If sufficiently consistent, the once collected water quality data could also provide valuable resources for subsequent use in scientific research and long-term monitoring. We examined the spatial and temporal coherence of the archived data resources stored in the environmental information system of the Finnish Environmental Administration (the Hertta-PIVET register). We used phytoplankton chlorophyll-*a* and primary productivity data collected during 1971–2006 as sample resources for environmental studies on the highly fragmented SW coast of Finland (Northern Baltic Sea). 733 sampling stations were categorized according to the total number of sampling days, the consistence of sampling, the number of representative years and the continuity of sampling. Considerable spatial and temporal inconsistencies were observed, making the accumulated data resources rather unsuitable for many types of environmental studies. Synchronization of sampling activities could improve the representativeness of spatial and temporal coverage of regional sampling. Strategic planning of sampling is required to achieve more concerted data generation activities and to facilitate long-term spatially representative analyses.

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Introduction

The development of geographical information systems (GIS) has opened up new opportunities for the storing and analysis of large quantities of environmental data. In the study and monitoring of surface water, GIS facilitates the effective integration of various datasets and their further analysis and simulations (e.g. Fedra 1995; Kitsiou & Karydis 2000; Liu et al. 2003). Space-borne remote sensing appears particularly cost-efficient as a method of assessing water quality over large areas (e.g. Muller-Karger 1992), and is also used increasingly to monitor the Baltic Sea (e.g. Siegel et al. 1999a, 1999b; Härmä et al. 2001; Zhang et al. 2002; Erkkilä & Kalliola 2004; Darecki et al. 2005; Vepsäläinen et al. 2005; Kutser et al. 2006). Large-scale assessments of environmental conditions in the Baltic are indeed needed, since environmental deterioration is affecting the entire sea area as a whole (Bonsdorff et al. 2002; HELCOM 2003; Rönnberg & Bonsdorff 2004).

In contrast to approaches based on remote sensing, traditional water monitoring focusing on specific locations is also essential. In many regions where waters are affected by human activity, water quality is systematically monitored in order to produce information for environmental management and decision-making (e.g. Chapman 1996; Anon. 2003a; U.S. EPA 2003). *In situ* monitoring is performed by visiting fixed stations by ship or boat; the water samples collected are analysed in the laboratory. This methodology has been a standard already for decades (e.g. Allan et al. 2006), and despite the development of other techniques it is still the best way to provide exact measurements about water bodies of special interest. Archived results from laboratory analyses also provide valuable data for long-term monitoring (e.g. Kirkkala et al. 1998; Hänninen et al. 2000) and for ground truthing of remote sensing surveys and GIS models (e.g. Kuusisto et al. 1998; Korpinen et al. 2004; Dzwonkowski & Yan 2005; Edelvang et al. 2005). Methodological assessments concerning the scientific applicability of data derived from standard field monitoring programmes have nevertheless been rather scanty (Dixon & Chiswell 1996), although the spatial design of sampling efforts has recently gained interest (e.g. Strobel et al. 2000; Danielsson et al. 2004). Aspects of water policy in general (e.g. Urquhart et al. 1998; Townend 2002) and the EU Water Framework Directive (WFD) in particular are examples of such efforts, which would benefit from an enhanced understanding of the re-use possibilities of archived water monitoring data (e.g. Borja et al. 2004; Borja 2005; de Jonge et al. 2006).

In Finland, the majority of *in situ* water quality data in coastal waters is collected as part of environmental monitoring and research programmes (Niemi & Heinonen 2003; Niemi et al. 2006). The data are mainly stored in the environmental information system "Hertta", maintained by the Finnish Environment Institute (Niemi et al. 2006). More precisely, data on surface waters are stored in Hertta's sub-system for the State of Finland's Surface Waters, entitled "PIVET". Most of the data available in Hertta-PIVET come from local pollution control monitoring programmes, established in order to monitor the impact of municipal and industrial waste waters or other environmentally hazardous activities (Finnish Environment Protection Act 2000; Niemi et al. 2006). In addition to these, data from national and regional monitoring programmes are included in the system, representing the Environmental Administration's efforts to assess the status of areas not monitored by other efforts (Anon. 1990a; Niemi et al. 2006).

Although the data stored in the Hertta-PIVET register come from distinct origins, they could provide valuable resources for subsequent use in scientific research and long-term monitoring. This, however, requires that the data resources be sufficiently consistent for such use; the duration of active sampling is one of the most fundamental features of data quality in a time series analysis (e.g. Burt 1994; Niemi & Heinonen 2003). Temporal and spatial consistency is especially critical on the SW Finnish coast, where sea areas are highly fragmented and sea currents are complex (Virtaustutkimuksen neuvottelukunta 1979; Helminen et al. 1998; Kirkkala 1998; Tolvanen & Suominen 2005). These conditions provide a true challenge for the effective and rational execution of water monitoring and *in situ* sampling. Moreover, this is also an area where different environmental interests abound due to the diversity of human activities practiced in the region. Many of these activities, such as lively leisure activities, aquaculture and heavy sea traffic, are mutually incompatible and affect the seawater quality; this calls for reliable and spatially representative water monitoring data and high-quality spatial-temporal models to support decision-making (Kirkkala 1998; Rajasilta et al. 1999; Jansson & Stålvant 2001; Ojala & Louekari 2002; Peuhkuri 2002).

The present study evaluates the temporal and spatial coherence of data resources on phytoplankton in the coastal waters of Southwest Finland, archived in the Hertta-PIVET register. Differences in the objectives and implementation of the monitoring and research programmes that have produced data for the Hertta-PIVET register evidently have an effect on the spatial and temporal distribution of sampling efforts. Here we examine the overall coherence of the Hertta-PIVET data resources from the regional point of view, as such a geographical approach is often used in environmental studies. We use the variables chlorophyll-*a* and primary productivity as specific cases to examine the coherence of the data resources; both variables describe aspects of the biological status and productivity of surface waters (e.g. Chapman 1996). Yet phytoplankton is so highly dynamic an element in surface waters that traditional *in situ* sampling may not be adequate to capture detailed spatial patterns or temporal changes taking place within a particular site (e.g. Edelvang et al. 2005). Chlorophyll-*a* is an estimate of phytoplankton biomass; it is widely used in spatial research, as it also is one of the properties that can be effectively captured by multi-spectral remote sensing (e.g. Liu et al. 2003; Darecki et al. 2005). Any application of such automated surveys, however, requires consistent *in situ* data for purposes of methodological training and quality assessment.

Study area

The Baltic Sea is a non-tidal brackish inland sea in northern Europe; the Archipelago Sea and the Bothnian Sea are located in the northern part of the Baltic Sea. This study focuses on those sea areas that are administered by the Southwest Finland Regional Environment Centre (SFREC, a regional environmental authority) and are situated approximately between 21°–23° E in longitude and 59°40′–62° N in latitude (Fig. 1). The study area is characterised by the strong seasonality of the boreal climate. The coastal waters are usually ice-covered during winter, albeit wide variations in ice formation occur between different years (HELCOM 1993, 2002). Rapid isostatic land uplift has altered the landscape of these areas following the deglaciation of 9500–9000 BP, the rate of the annual land uplift being circa 4–5 mm in the Archipelago Sea and c. 5–6 mm in the southern and central parts of the Gulf of Bothnia (Ristaniemi et al. 1997).

The coasts of the Archipelago Sea and the Bothnian Sea are characterised by varied geomorphic characteristics, including numerous islands, skerries, straits, bays and open sea areas (Tolvanen et al. 2004). According to Granö and Roto (1989), the shores closest to the mainland in the Archipelago Sea and in the southern Bothnian Sea are mainly composed of fine sediments, while in the outer archipelago rocky skerries prevail. In between these extremes, the prevalent form is a belt of predominantly moraine shores, approximately 10–30 km in width. In the northern part of the study area (north of 61° latitude), the shores mainly consist of fine sediment belts attached to mainland tills.

Topographically the most salient feature of the archipelago is the relative distribution of land and sea areas. The Archipelago Sea is usually divided into inner, middle and outer areas based on the proportional distribution of land and sea (the physical geography of coastal zoning is discussed by Granö 1981, 2001; see also Fig. 1 for the coastal

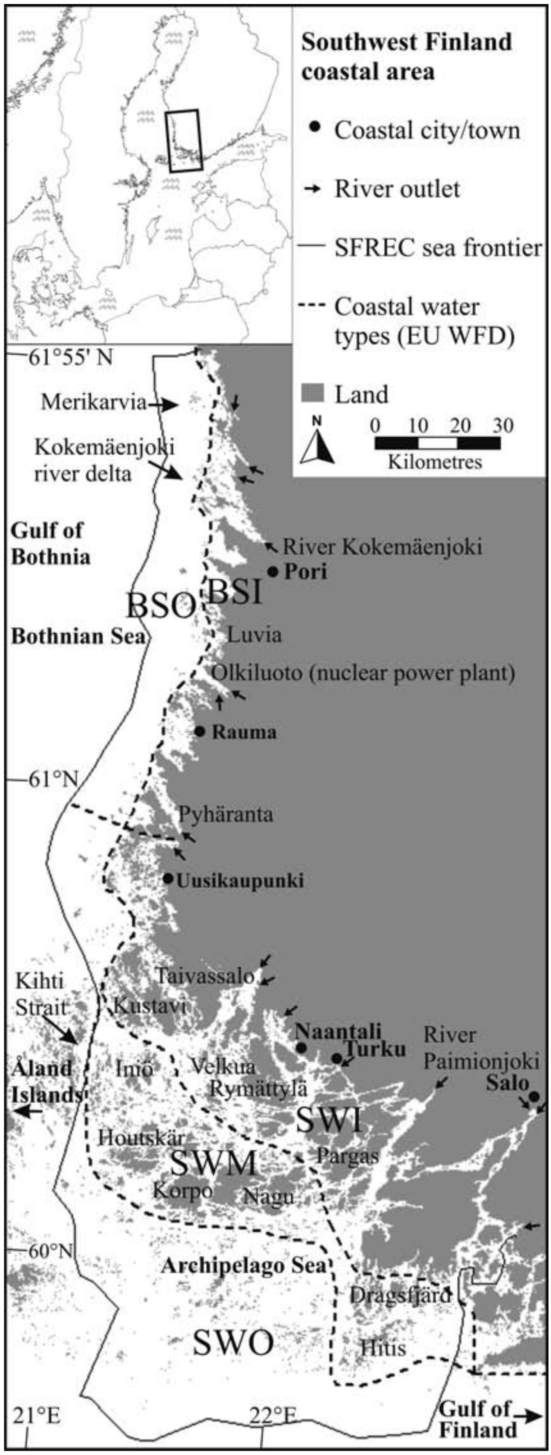


Fig. 1. Map of the study area in SW Finland. The Coastal Water Types of the EU Water Framework Directive (SWI, SWM, SWO, BSI, BSO) illustrate the coastal zoning, which is profoundly based on the morphology and topography of the coastal region (drawing according to Vuori et al. 2006: 21). Coastal water types have been defined according e.g. to wave exposure, depth, duration of ice cover and salinity (Vuori et al. 2006). In this article, "inner archipelago/coastal region" refers approximately to areas of inner coastal water types (SWI and BSI). "Middle archipelago" refers to the island-rich central area of the Archipelago Sea, which corresponds approximately to the area of coastal type SWM. "Outer archipelago/open sea areas" refers to areas of coastal types SWO and BSO.

water types of the EU Water Framework Directive). In the inner archipelago terrestrial areas prevail over sea areas; in the middle part their proportions are almost equal, and in the outer archipelago open water prevails. The underwater morphology is also highly variable, with numerous faults, sills and depression basins of different shapes and sizes. The region is in general shallow, with an average depth of c. 23 meters, but it also has many deeps; the deepest trench is 146 meters in depth. The largest river discharging into the Archipelago Sea is the Paimionjoki, with a mean discharge of circa 7 m^3/s.

In the Bothnian Sea, large embayments and small groups of islands make up a relatively open and narrow coastal region. The coastal waters of the Bothnian Sea are shallow in the area of inner bays and island groups, deepening rather smoothly towards the open sea. Near the islands water depth is mostly less than 10 meters; the 20-meter depth contour is usually at a distance of 10–20 kilometres from the coastline, and the 50-meter depth contour some 10 kilometres further out (Kirkkala & Oravainen 2005). The most prominent geomorphological characteristic of the Bothnian Sea coast is the delta of the Kokemäenjoki River (Fig. 1), with a mean discharge of circa 230 m^3/s.

Baltic Sea waters are stratified both thermally and by salinity (HELCOM 2002). The water currents in the archipelago and coastal areas are highly variable. In open water season, locally variable wind conditions have a major effect on the seawater stratification and the directions and velocities of coastal currents (Virtaustutkimuksen neuvottelukunta 1979; HELCOM 1993; Helminen et al. 1998). However, Baltic surface waters show a slow counter-clockwise circulation, caused by the Coriolis force and the morphology of the Baltic Sea basin (HELCOM 1993). The surface waters therefore tend to flow from the Gulf of Finland through the archipelago areas to the eastern coast of the Bothnian Sea. Water exchange is apparently facilitated by bedrock fractures, located between the Archipelago Sea and the Åland Islands and oriented north to south (Palosuo 1964; Helminen et al. 1998).

The largest city in the Archipelago Sea is Turku. The population in the Turku region is nearly 0.3 million, and the permanent population in the middle and outer archipelago is under twenty thousand. The population on the coast of the Bothnian Sea is smaller than on the mainland facing the Archipelago Sea. The largest city is Pori, with a population of 76 thousand. The Bothnian Sea coast, especially near the cities, has heavy paper, metal and chemical industries, as well as the Olkiluoto nuclear power plant (Sarvala & Sarvala 2005). The Archipelago and its catchment area have intensive practice of fish farming and agriculture (Kirkkala 1998).

Material and methods

Data on phytoplankton, i.e. chlorophyll-*a* and primary productivity measurements and their sampling stations, were retrieved from the Hertta-PIVET register in the autumn of 2003 and in March 2007. The most recent data records included in this study were collected during September 2006. Some individual results for 2006 may be missing from our data, as they may not yet have been stored in the system at the time of our data search. The way we collected data from the Hertta-PIVET register did not take into account the different monitoring contexts and origins of the stored data. Consequently, this study highlights the possibilities and pitfalls of using this data archive as a data resource for long-term spatial analyses.

Only composite samples (with an upper depth marked as 0.0 m) were taken into account, since in Finnish coastal waters the majority of phytoplankton measurements are drawn from such samples. Composite samples are compiled by mixing discrete water samples taken from different water layers to a depth twice that of the Secchi Disk, often measured using the white cap of the water sampler (e.g. Anon. 1973, 1982; Mäkelä et al. 1992). These samples reveal the general status of the productive surface layer, but yield no information on the vertical profile of the water body.

The study included only samples collected during the open water seasons of 1971–2006, from the beginning of May to the end of September (Drebs et al. 2002). In general, this is also the season of the most intensive water sampling efforts. The smallest unit of sampling activity was defined as one day. The number of analysis results may actually be higher under these conditions, since several samples may have been taken at the same station during a single day. We excluded from the data set sampling stations situated in small, almost enclosed bays penetrating deep into the mainland, since they represent coastal water quality only to a very limited extent. Three stations located near the wastewater discharge sites of the city of Turku and the towns of Kaarina and Pargas were also excluded. On the other hand, some stations located outside the SFREC administrative region border were included in the study (e.g. stations near the Kihti Strait and in the sea area of Pori; see e.g. Fig 2), if they belong to a monitoring programme specific to the region. Primary production ability (Table 1) was chosen to represent primary productivity; it has been analysed principally from composite samples, and its sampling has been regionally more evenly distributed than the sampling of primary production as such. The data selection process did not take into account differences in methods of laboratory analysis (Table 1). The sampling stations that belong to or have been involved in the monitoring programmes of the Finnish Environmental Administration are marked with a special symbol in Appendix 1 (see also Kauppila & Bäck 2001; Suomela 2003). Some of these stations and the majority of all the unmarked stations belong to the local pollution control monitoring programmes. Primary productivity has been analysed as part of the pollution control monitoring, but rarely in the monitoring programmes of the Environmental Administration (e.g. Kirkkala 1998, 2005; Kauppila & Bäck 2001).

After applying these criteria, a total of 733 sampling stations were included for further examination. In order to characterize the sampling effort at each of them, the stations were categorized according to the following criteria:

- *Total number of sampling days*. The number of days when water samples have been collected and analysed for a given variable during the study period 1971–2006. Two categories of sampling stations were established: occasional (total of 1–9 sampling days) and established (≥ 10 sampling days).
- *Consistence of sampling*. Three groups were formed according to the length of time covered by water sampling: consistent (sampling conducted during ≥ 20 years), semi-consistent (sampling conducted during 10–19 years) and irregular (sampling conducted during ≤ 9 years).
- *Number of representative years*. Reflecting recommended practices in water monitoring (e.g. Anon. 1973; HELCOM 2007), we considered that a minimum of three sampling days during the open water season is needed to regard the samplings as representative of a year. Naturally, an increasing number of sampling days will further increase the usability of the data collected at a station. In some tabulations the sampling stations were classified according to the number of representative years, as follows: ≥25, 20–24, 15–19, 10–14, 5–9 and 0–4.
- *Continuity of sampling*. Taking the year 2000 as a reference point, the sampling stations were divided into two categories: active (stations with samples taken in or after the reference year) and inactive.

With the aim of assessing the temporal and spatial qualities of the water sampling at different stations, data analysis was performed using two approaches for both chlorophyll-*a* and primary productivity. First, visual time series assessments and cross tabulations were performed to estimate the consistency, number of representative years and

Table 1. Data record and analytical properties of water sampling data collected from the Hertta-PIVET register (see also SFS 3049 1977; SFS 3013 1983; SFS 5772 1993).

PIVET code	Unit	PIVET code description
Phytoplankton chlorophyll-*a*		
CP E12	µg/l	Extraction in ethanol
CP E12;SP	µg/l	Extraction in ethanol; spectrophotometry, flow injection analysis, colourimetric
CP E19;SP	µg/l	Extraction in methanol; spectrophotometry, flow injection analysis, colourimetric
CP E2	µg/l	Extraction in acetone
CP E2;SP	µg/l	Extraction in acetone; spectrophotometry, flow injection analysis, colourimetric
CP E12;AF	µg/l	Extraction in ethanol; atomic fluorescence
Phytoplankton primary productivity (i.e. production ability)		
BPY N17	mg C/m³ 2h	Incubation for 2 hours in dark
BPY N18	mg C/m³ 2h	Incubation for 2 hours netto
BPY N19	mg C/m³ d	Incubation for 24 hours in dark
BPY N20	mg C/m³ d	Incubation for 24 hours neto

continuity of sampling efforts performed at different stations. The tables are rooted in the full bodies of data shown in Appendix 1, which gives the annual sampling regimes of all the individual stations. In order to simplify data analysis for long-term spatial pattern evaluation, we examined water samplings at annual and semi-monthly levels only. Secondly, the locations of differently sampled stations, as based on the above tabulations, were visualized in map form.

Data on chlorophyll-*a* are further used to study the development and distribution of water sampling activities during the open water seasons of consecutive years. We counted the numbers of chlorophyll-*a* sampling days for the first and second halves of each month of the open water season. All stations with a minimum of one day of chlorophyll-*a* sampling were included in the analysis. To investigate the spatial patterns of the annual samplings, maps were prepared to show data values representing six years.

Results

General trends in the sampling efforts

Of the 733 sampling stations included, chlorophyll-*a* was measured in 705 and primary productivity in 509 stations during the study period 1971–2006 (Table 2). Overall sampling intensity has been low in most of the individual sampling stations. In over a third of them sampling of both variables was performed less than ten times, and in half of them the total number of sampling days was less than twenty. The proportion of frequently sampled stations is low; only a fifth of the stations were sampled on more than 40 days (see also Appendix 1).

Table 2. Cumulative numbers of sampling stations of chlorophyll-*a* and primary productivity according to number of days with available analytical data.

	Number of sampling stations			
	Chlorophyll-*a*		Primary productivity	
Tot. number of sampling days / station	f_i	Cumul. %	f_i	Cumul. %
1–9	236	33.5	192	37.7
10–19	110	49.1	87	54.8
20–29	79	60.3	58	66.2
30–39	80	71.6	49	75.8
40–49	60	80.1	29	81.5
50–59	35	85.1	8	83.1
60–69	24	88.5	10	85.1
70–79	18	91.1	21	89.2
80–89	11	92.6	12	91.6
90–99	13	94.5	4	92.3
100–109	10	95.9	11	94.5
110–119	6	96.7	6	95.7
120–129	3	97.2	10	97.6
130–139	11	98.7	6	98.8
140–149	1	98.9	1	99.0
150–159	2	99.1	2	99.4
160–169	1	99.3	1	99.6
170–179	0	99.3	1	99.8
180–189	3	99.7	1	100.0
190–199	0	99.7		
≥ 200	2	100.0		
Total	705		509	
Max. value	248		185	

The overall distribution of the sampling stations is relatively uniform in the inner and middle parts of the coastal region, but in the outer archipelago and open sea areas there are only a few stations (Fig. 2). In the case of chlorophyll-*a*, both occasional (total of less than ten sampling days) and established (≥ 10 sampling days) stations are widely distributed, while in primary productivity sampling occasionally sampled stations abound mainly in the middle archipelago (Fig. 2).

In the temporal analysis, water sampling efforts were most intensive in the 1990s (Table 3, see also Appendix 1). The sampling efforts for chlorophyll-*a* increased steadily from the 1980s till the end of the 1990s, after which they began to decrease. Primary productivity was sampled more intensively than chlorophyll-*a* until the mid-1980s. The peak intensity in primary productivity sampling occurred in the early 1990s; since then, sampling intensity has decreased.

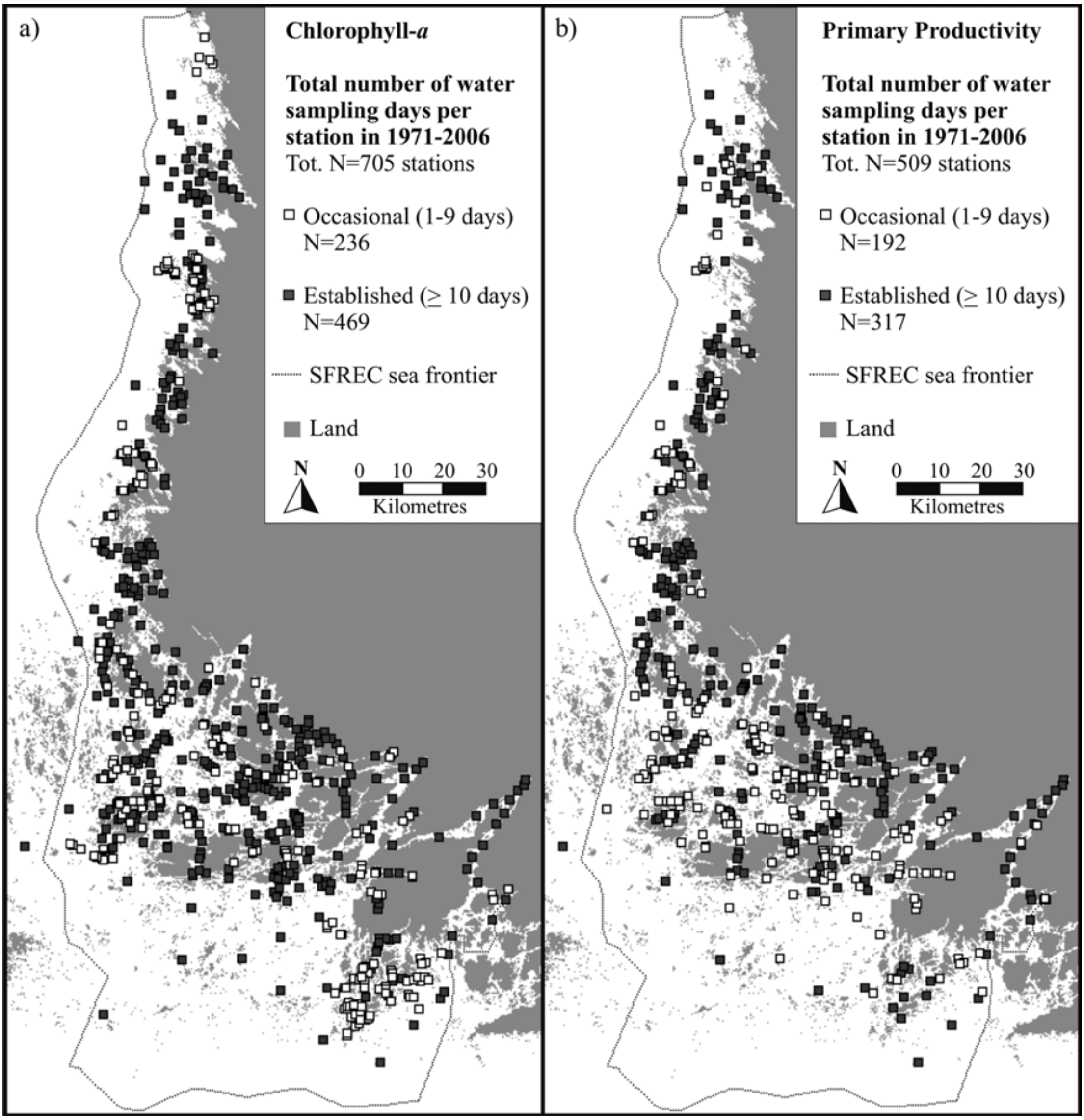


Fig. 2. Locations and numbers of sampling days of the phytoplankton sampling stations considered in this study. a) sampling stations of chlorophyll-*a*; b) sampling stations of primary productivity

Table 3. Development of sampling activities during the study period of 1971–2006. Only established sampling stations (sampled in ≥ 10 days) are included (see Appendix 1 for detailed information on individual stations).

		Total number of sampling days during open water seasons					
		Chlorophyll-*a*			Primary productivity		
Period	Years	f_i	%	Cumul.%	f_i	%	Cumul.%
1971–1974	4	1	0.005	0.005	30	0.20	0.20
1975–1979	5	144	0.69	0.69	714	4.89	5.09
1980–1984	5	1564	7.45	8.14	2047	14.01	19.11
1985–1989	5	3129	14.90	23.04	2651	18.15	37.26
1990–1994	5	4941	25.53	46.56	3553	24.33	61.58
1995–1999	5	5274	25.11	71.67	2995	20.51	82.09
2000–2004	5	4159	19.80	91.48	2225	15.23	97.32
2005–2006	2	1790	8.52	100.00	391	2.68	100.00
Total		21,002			14,606		

Temporal consistency of the data resources

The sampling of chlorophyll-*a* has been consistent at 142 stations, corresponding to 30% of all the sampling stations (Table 4, Appendix 1). Of these, 14 stations have samplings representing at least 25 years, while 50 stations have them representing 20–24 years. These stations occur as dense clusters near the cities of Turku, Uusikaupunki and Rauma; in contrast, stations representative of a lower number of years are scattered widely along the coast near the mainland (Fig. 3). Semi-consistent sampling covering 10–19 years has been conducted at 221 stations (47% of all sampling stations), the most representative of them being located near the municipality of Kustavi and the city of Pori. Semi-consistent stations, with poorer annual representation, abound especially in the central archipelago region. Finally, at 23% of stations data collection has been irregular or has already ceased. These stations appear clustered in some parts of the middle archipelago in particular. At some of these stations data collection did not start until the late 1990s, but data production has been annually representative since then (Appendix 1).

Primary productivity has been measured on fewer occasions, but the number of consistently sampled stations is relatively high, totalling 122 (38% of all stations) (Table 4, Appendix 1). Stations representative of a good number of years,

Table 4. Frequency of sampling stations in different categories according to consistency of sampling and number of representative years. Only established sampling stations (sampled ≥ 10 days) are included (see Appendix 1 for detailed information on individual stations).

	Number of representative years							
	≥ 25	20–24	15–19	10–14	5–9	0–4	Inactive	Total
Chlorophyll-*a*								
Consistent	14	50	31	18	8	21		142
Semi-consistent			10	21	75	101	14	221
Irregular					13	59	34	106
Total	14	50	41	39	96	181	48	469
Primary Productivity								
Consistent	16	53	10	4	3	29	7	122
Semi-consistent			4	4	6	43	33	90
Irregular					8	12	85	105
Total	16	53	14	8	17	84	125	317

however, are more clustered than in the case of chlorophyll-*a*, and mainly occur very close to the mainland (Fig. 4). Semi-consistent data resources are available from 105 stations, many of which are located in the middle archipelago zone. Primary productivity sampling ceased at nearly 40% of the stations in general before 2000, most often between 1993 and 1997. Similarly, sampling seems to have ceased in the 2000s, especially in a majority of the representative sampling sites (Appendix 1).

The seasonal assessment of the data resources on chlorophyll-*a* indicates relatively good temporal distribution of sampling efforts since the 1980s

Table 5. Numbers of sampling days for chlorophyll-*a* during the open water seasons of 1971–2006. All stations where chlorophyll-*a* was sampled are included (N = 705). The five most sampled years for each half-month are underlined.

	Numbers of sampling days for chlorophyll-*a* during the open water seasons											
	May		June		July		August		September			
Year	1–15	16–31	1–15	16–30	1–15	16–31	1–15	16–31	1–15	16–30	Total	%
1971	–	–	–	–	–	–	–	1	–	–	1	0.005
1972	–	–	–	–	–	–	–	–	–	–	0	0.000
1973	–	–	–	–	–	–	–	–	–	–	0	0.000
1974	–	–	–	–	–	–	–	–	–	–	0	0.000
1975	–	–	–	–	–	–	–	6	–	–	6	0.027
1976	–	–	–	–	–	–	–	–	1	–	1	0.005
1977	–	–	–	–	–	–	3	1	–	–	4	0.018
1978	–	–	6	10	1	2	10	–	–	–	29	0.132
1979	7	1	21	20	7	13	18	11	8	4	110	0.499
1980	4	17	14	12	21	7	12	24	–	–	109	0.495
1981	14	–	70	52	47	40	26	60	4	–	313	1.420
1982	1	9	72	17	28	17	53	30	5	4	236	1.071
1983	10	43	46	55	26	60	79	62	26	1	408	1.852
1984	12	32	60	58	84	103	106	97	24	30	606	2.750
1985	22	57	45	27	66	78	64	102	90	49	600	2.723
1986	10	43	46	56	71	109	63	142	35	33	608	2.759
1987	10	25	52	46	66	113	63	136	47	18	576	2.614
1988	17	47	31	84	81	177	72	225	54	14	802	3.640
1989	14	71	53	90	163	140	133	134	145	26	969	4.398
1990	33	43	88	109	173	177	153	178	131	23	1108	5.028
1991	35	44	45	82	133	197	96	167	145	27	971	4.407
1992	29	45	60	102	138	147	134	137	129	30	951	4.316
1993	78	43	139	61	182	112	181	210	112	26	1144	5.192
1994	71	61	97	38	109	113	178	133	73	10	883	4.007
1995	81	56	57	48	196	92	174	215	130	13	1062	5.820
1996	80	57	104	145	152	210	160	203	125	32	1268	5.754
1997	91	55	64	81	129	69	146	191	75	57	958	4.348
1998	85	51	76	35	108	102	156	130	92	28	863	3.916
1999	73	67	147	109	148	170	152	205	114	30	1215	5.514
2000	28	47	57	87	91	176	169	155	104	19	933	4.234
2001	30	51	54	47	60	200	157	206	56	13	874	3.966
2002	23	29	29	30	75	175	216	161	125	22	885	4.016
2003	29	28	71	63	126	93	180	104	101	25	820	3.721
2004	31	52	47	65	163	87	151	177	29	60	862	3.912
2005	10	59	104	91	168	126	141	203	79	48	1029	4.670
2006	9	63	75	35	131	155	155	118	47	43	831	3.771
Total	937	1196	1830	1755	2941	3260	3401	3924	2106	685	20,035	100.00
%	4.3	5.4	8.3	8.0	13.3	14.8	15.4	17.8	9.3	3.1		

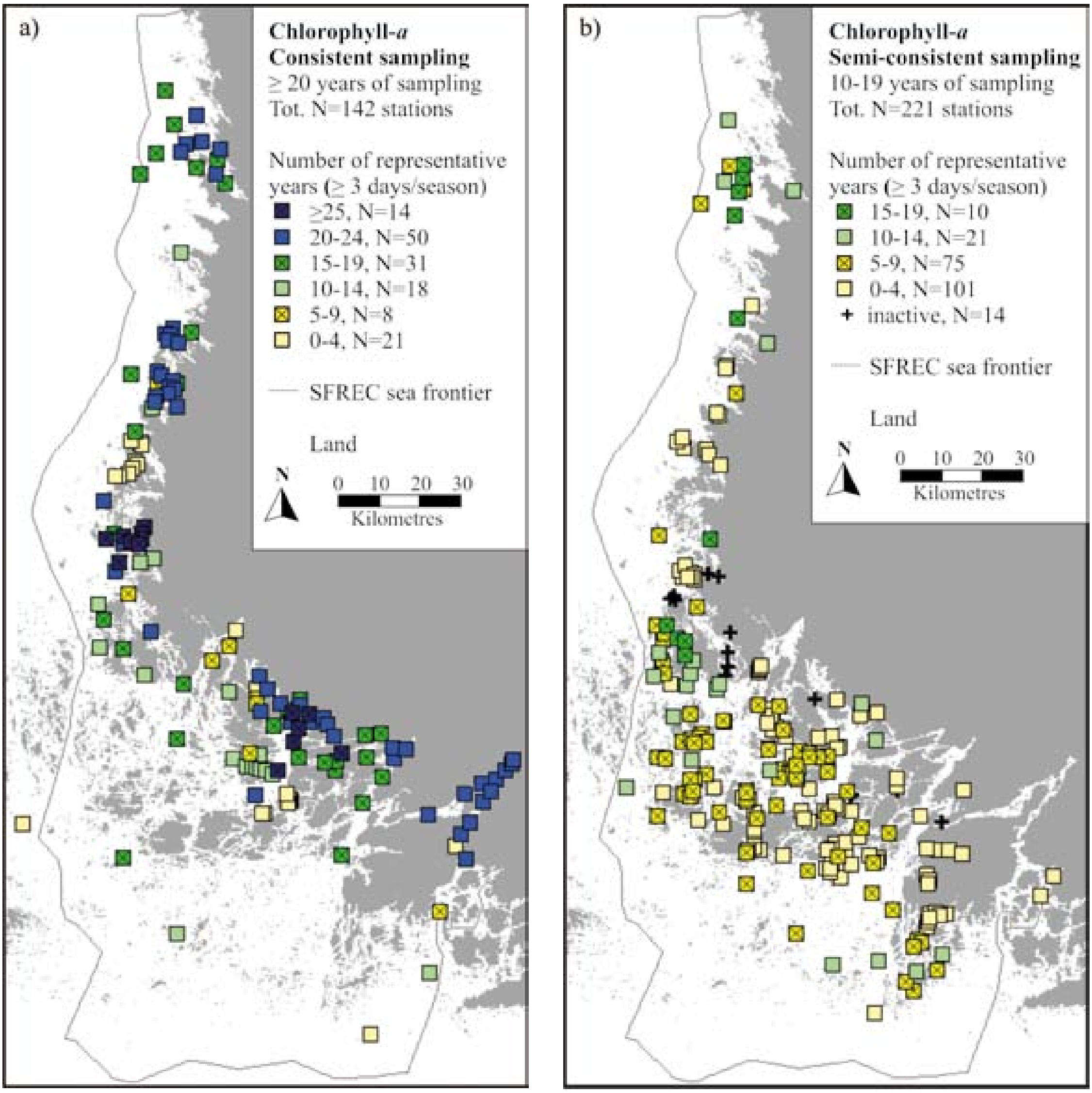
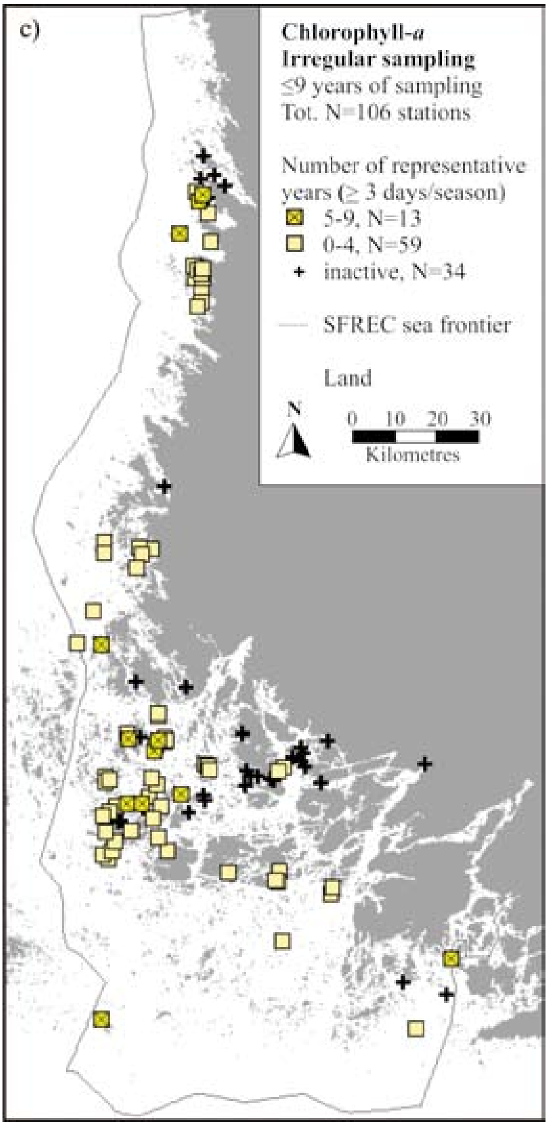


Fig. 3. Spatial patterns of chlorophyll-*a* sampling stations with different data records (see also Table 4). a) consistently sampled stations. b) semi-consistently sampled stations. c) irregularly sampled stations.

(Table 5). However, sampling activities have been weaker in the early and late part of the season, while the highest activities have occurred in the months of July and August. A spatial assessment of the data (Fig. 5) indicates that sampling campaigns have often moved about widely over the study area; the same stations have been sampled only once or twice during the growing season. The migratory and irregular pattern of sampling efforts is further evidenced in a comparison of consecutive years. In the 2000s, samplings in the months of July and August have covered most of the study area and especially the central Archipelago Sea, while in the early and late parts of the open water season samplings have mainly been carried out close to the mainland and urban centres.



Discussion

The value of long-term data resources is indispensable in any temporal analysis of the environment (e.g. Burt 1994; Urquhart et al. 1998; Hiscock et al. 2003; Niemi & Heinonen 2003; Parr et al. 2003). Consistent long-term monitoring data may reveal important trends or patterns and raise valid questions, yet they may not be visibly solving any concrete environmental problems. The added value of consistent data resources may also come up in the future, since not all relevant questions and hypotheses are known at the time a monitoring regime is set up (Burt 1994, 2003). Thus, for strictly scientific reasons, continuity of monitoring efforts is crucial.

The irregularities and spatial bias of sampling efforts, as detected in this study, are due to the development history and purpose of the Hertta-PIVET register. This situation has an understandable historical background, but there may be possibilities to come across a more coordinated sampling regime that will facilitate subsequent uses of the accumulating data resources.

Past coastal water monitoring in SW Finland

The development of an adequate water sampling regime for the coastal areas of Southwest Finland has been challenging task. The complex geomorphology and complicated hydrodynamic conditions of the region (Tolvanen et al. 2004; Tolvanen & Suominen 2005), combined with the presence of a strong human influence with diverse environmentally hazardous activities, call for a dense network of water monitoring stations. Furthermore, the water monitoring efforts in the region should be flexible enough to reflect the concurrent needs of the society (Niemi & Heinonen 2003). These pressures are being met by regular water monitoring, whose development can be divided into three different phases.

In the 1970s and early 1980s, the monitoring of chlorophyll-*a* and primary productivity started in the inner coastal waters near the mainland, with additional solitary sampling stations established by the Environmental Administration in the outer archipelago and by the open sea (see Appendix 1). Most of the stations were established to monitor local pollution, with the consequence that they came to be distributed in clusters. This pattern is particularly pronounced along the narrow coastal zone of the Bothian Sea, where local pollution control monitoring programmes have been carried out since the 1960s (Kirkkala 2005) to monitor the impact of the region's heavy industries and urban centres (Pori, Rauma, Uusikaupunki). In the Archipelago Sea, the vicinities of the city of Turku and the town of Naantali reveal the same setting, but there is also a rather dense network of other long-term sampling stations in the inner bays and sounds of the region (Finnish Environmental Administration 2006).

During the second phase, from the mid-1980s to the mid-1990s, a group of water sampling stations were established by the environmental au-

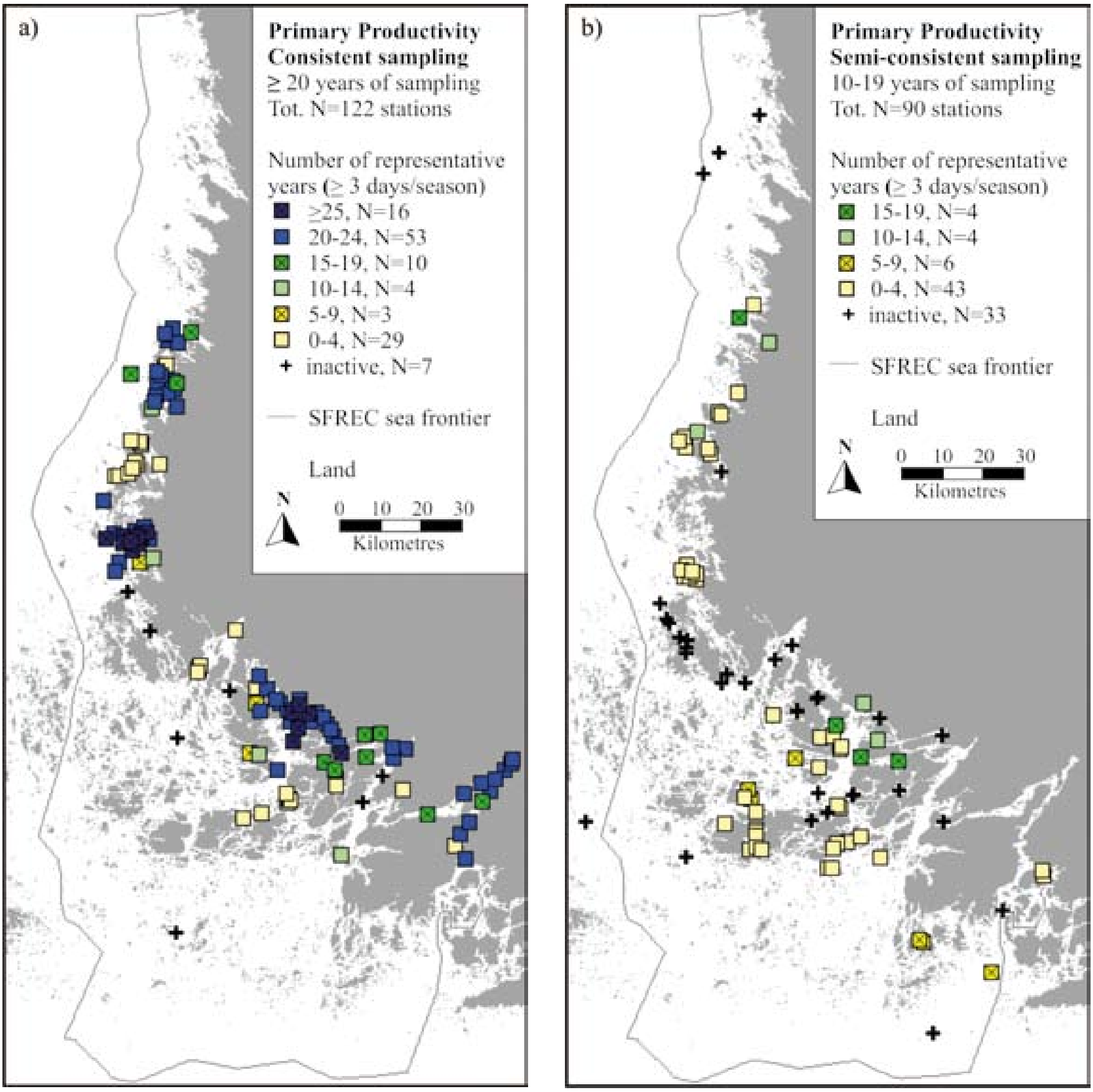
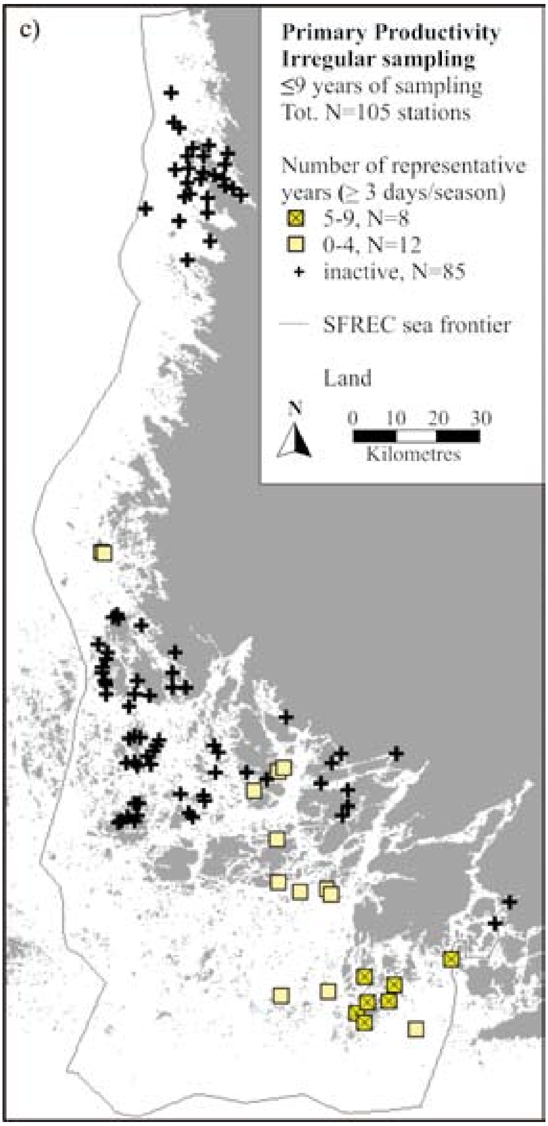


Fig. 4. Spatial patterns of primary productivity sampling stations with different data records (see also Table 4). a) consistently sampled stations. b) semi-consistently sampled stations. c) irregularly sampled stations.

thorities to complement the previously existing network (e.g. Anon. 1990b). Most of the new stations were established in the middle archipelago, but the sampling of outer archipelago and open sea areas was improved as well. Many of the new stations formed part of the fish farming monitoring programmes that started in the 1980s (Finnish Environmental Administration 2006). Since 1989, the Southwest Finland Regional Environment Centre has also carried out regular mappings of the status of the productive surface water layer in the Archipelago Sea (e.g. Suomela 2003, see also Appendix 1). Together, these sampling networks have built up a spatially representative setting in the middle and outer Archipelago Sea areas. In the Bothnian Sea, water sampling efforts have retained their focus on local pollution control monitoring programmes.

The third phase, from the mid-1990s onward, has reflected changing water monitoring strategies



(Anon. 1997, 2003b). Many international obligations, such as the introduction of the EU Water Framework Directive, have affected the development of coastal monitoring in recent years (Anon. 2000; Niemi & Heinonen 2000, 2003). To rationalize the work, sampling efforts have re-allocated. Some stations have been abandoned, and the frequency of water samplings has decreased in many of the ongoing stations. Interest in primary productivity also appears to have ceased, apparently because of its measurement is arduous and the results uncertain and highly variable (Kangas & Pitkänen 1990; Kotilainen 2007). This decreasing trend also characterizes the monitoring of chlorophyll-*a*, but a relatively dense network of sampling stations still remains. It should be acknowledged, however, that some of the abandoned stations were originally planned to produce only short-term data. For example the impact of fish farming was monitored with a particular emphasis on the middle Archipelago Sea during the 1980s and 1990s (Honkanen & Helminen 2000). Since the peak years of the early 1990s, the intensity and production of fish farming has declined considerably (Kaukoranta 2005).

Each monitoring programme of the local pollution control is planned individually according to its specific objectives, and they are subsequently revised according to the contemporary activities of the polluters (Niemi et al. 2006). This increases the spatial incoherence and temporal variation of sampling efforts. In general, sampling is often conducted during the later part of the summer when surface waters are thermally stratified and cyanobacteria dominated phytoplankton production is at its maximum (e.g. Kauppila & Bäck 2001). Only at some stations, water quality sampling is performed several times a year to detect seasonal variations of the water quality. For example, 16–20 samples are collected throughout the year in the intensive coastal monitoring programme (see Appendix 1; Kauppila & Bäck 2001; Niemi et al. 2006).

The consequence of this varied development history is that the Hertta-PIVET register contains data from a number of different sampling stations, but only at a few of them monitoring has been regular over long term. Furthermore, the consistently sampled stations are geographically biased, as most of them are located in spatially restricted parts of the inner coast. On the middle and outer coasts, coherent data series suitable for long-term analyses are available from only a small number of stations (Kirkkala et al. 1998; Hänninen et al. 2000). Since many of these stations are located in the mixing areas of different water masses, the utility of their data records is further restricted unless other spatial data sources concerning concurrent seawater conditions are available (Erkkilä & Kalliola 2004). For example the detection of temporal trends in surface water eutrophication in such areas would require much more comprehensive field-controlled data than are currently available (e.g. Suomela 2003). This restriction makes it difficult to distinguish between different water areas

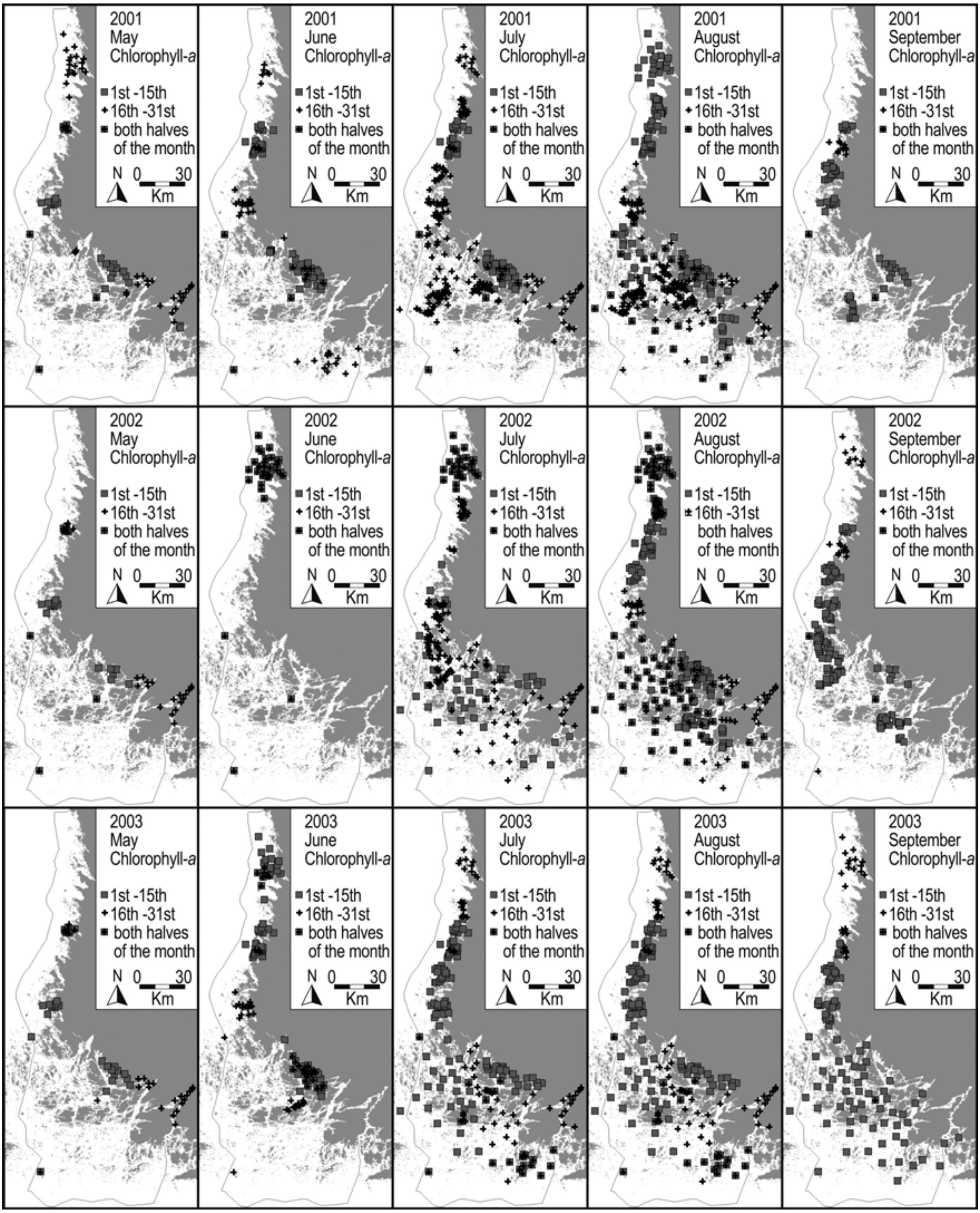
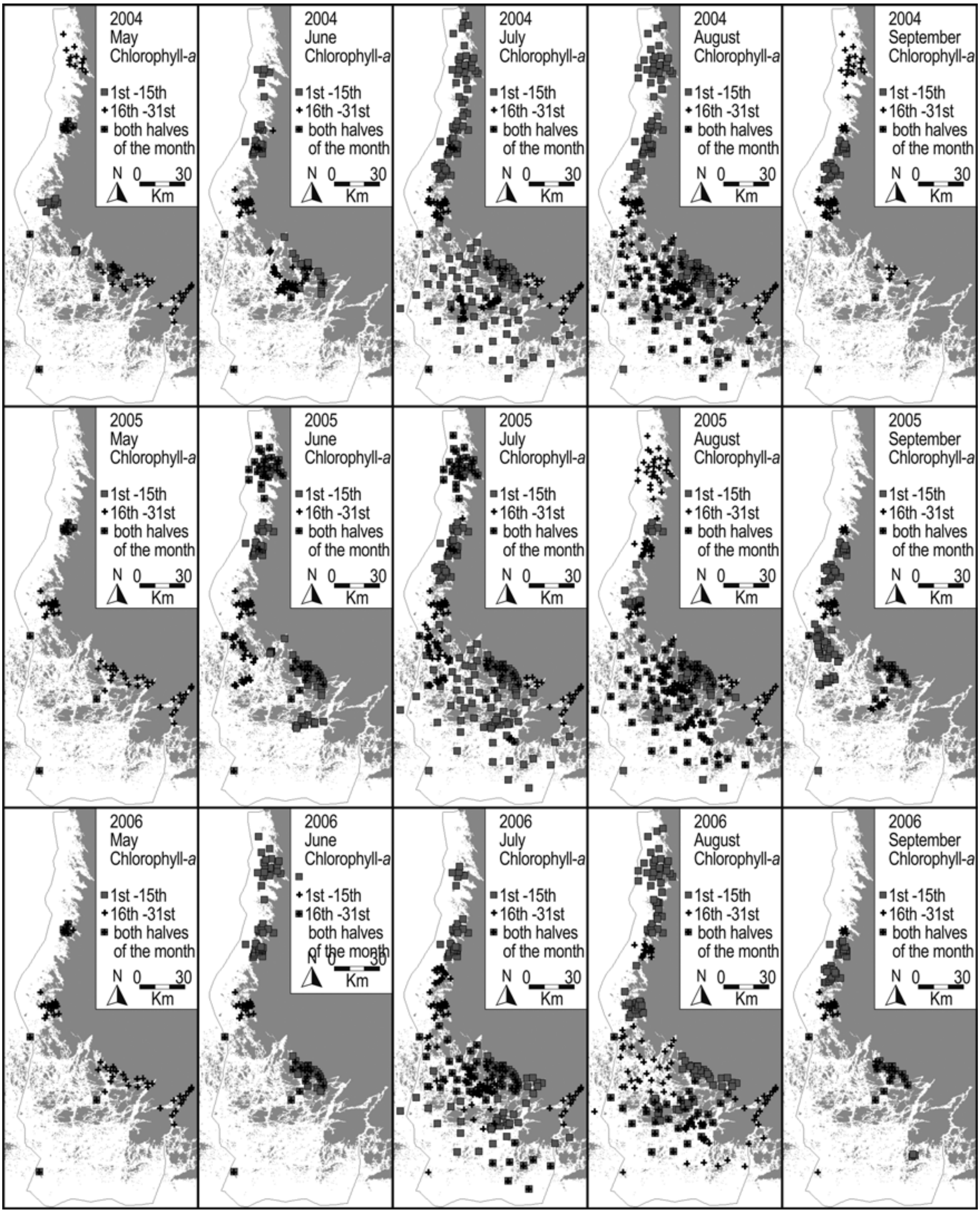


Fig. 5. Spatial distributions of sampling stations for chlorophyll-*a* during open water seasons, 2001–2006. For more details see Table 5.


2004
May
Chlorophyll-a
2004
June
Chlorophyll-a
2004
July
Chlorophyll-a
2004
August
Chlorophyll-a
2004
September
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2006
July
Chlorophyll-a
2006
August
Chlorophyll-a
2006
September
Chlorophyll-a
1st -15th
16th -31st
both halves
of the month
N
0
30
Km

for management purposes in the central archipelago region, which is problematic for the implementation of the EU's Water Framework Directive (de Jonge et al. 2006; Vuori et al. 2006).

Towards more concerted and cost-efficient actions

In the Baltic Sea, the high natural variability of the phytoplankton productivity emphasizes the significance of both wide coverage by the monitoring stations and the availability of long-term data records. Such data resources would facilitate important environmental assessments, such as the evaluation of spatial and temporal changes in the trophic state of seawaters (Raateoja et al. 2005). These demands, however, are to some extent incompatible: short or irregular samplings that produce data covering extensive areas can be useful in a given, specific context, but the possibilities of later use of the data thus generated are limited. Despite the considerable water monitoring efforts that have been carried out during recent decades in SW Finland, the data records they have yielded are undesirably problematic in terms of their reuse in spatial and temporal studies. The necessity of developing co-operation, coordination and cost-effectiveness, as well as interaction between research and monitoring is obvious, as recognised also in some other instances (Anon. 1997, 2003b).

This limited usefulness of the available data resources does not match the amount of resources invested in their generation (e.g. Niemi & Heinonen 2000, 2003). It should of course be recognised that many monitoring campaigns are motivated by local short-term needs only, not by any concern to create data resources for other purposes. Despite this constraint, however, it makes sense to aim at the creation of more comprehensive and regionally representative long-term data resources simply by integrating the efforts of individual water monitoring programmes (Schiff et al. 2002). Ideally, good coordination would at the same time both reduce costs and improve the future usefulness of the archive records of water monitoring data. Such coordinating efforts would not necessarily entail any fundamental changes in the individual monitoring programmes, but rather certain modifications in their methodology, intensity, regularity and simultaneity.

To some degree this has already been successful in Finland, as data derived from many different monitoring campaigns are incorporated into the same data storage system, the Hertta-PIVET register. In the light of the assessment presented here, however, spatial and temporal inconsistencies make the accumulated data resources less suitable for environmental studies than might be expected based on the considerable size of the data archives. Synchronization and strategic planning is therefore called for to bring about more concerted data generation activities. Ideally, not only would the short-term goals of each individual water sampling be met, but the joint register would also facilitate long-term spatially representative analyses. This requires that the labour-intensive field sampling regimes be assessed scientifically, taking into account both the short-term and long-term perspectives (e.g. Urquhart et al. 1998; Danielsson et al. 2004; Håkanson 2007). In addition, an integrated application of remote sensing techniques would enhance cost-efficiency in coastal water monitoring, due to their ability to express spatially representative time snapshots at a level that cannot be reached by point sampling (Erkkilä & Kalliola 2004; Kutser 2004; Reinart & Kutser 2006).

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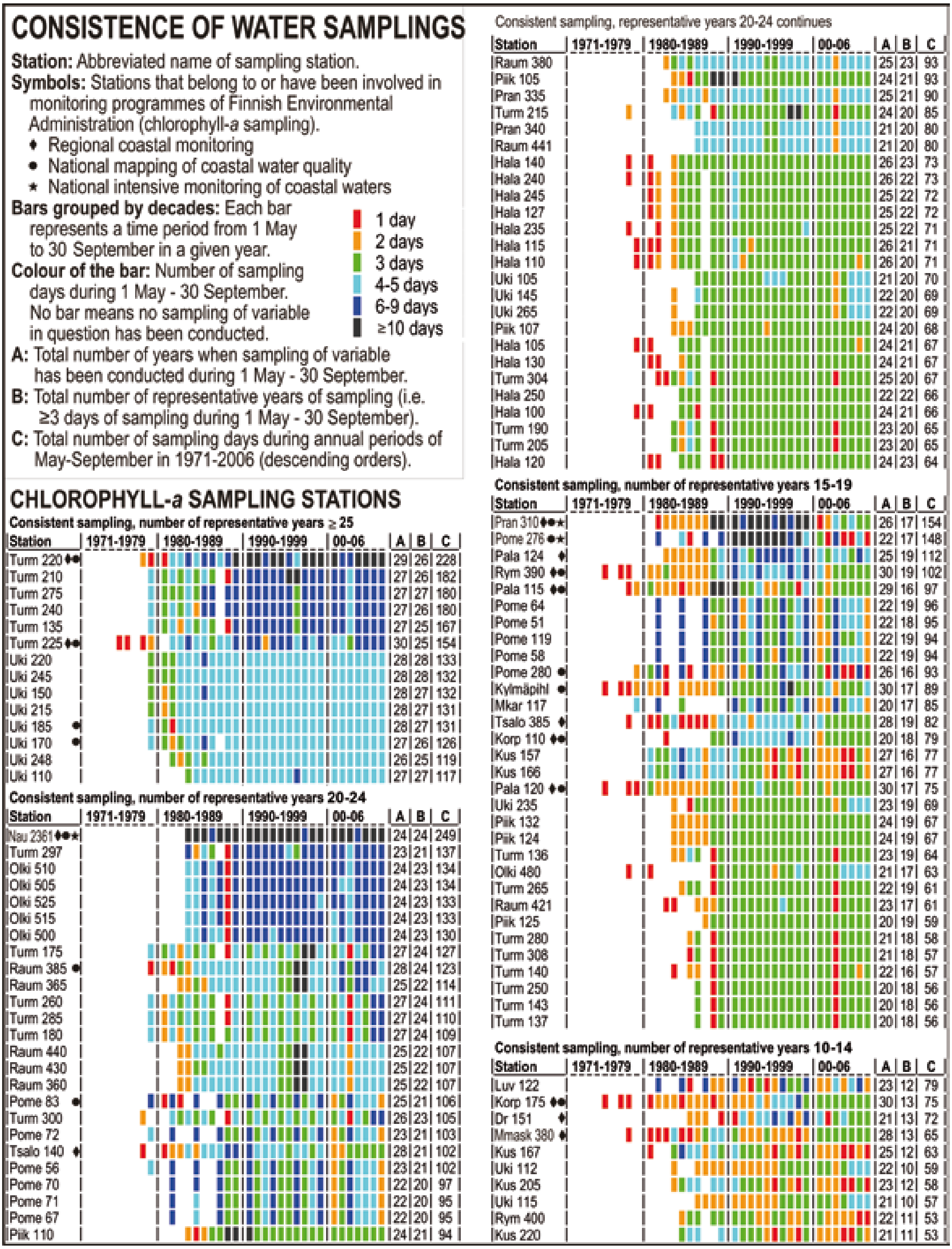
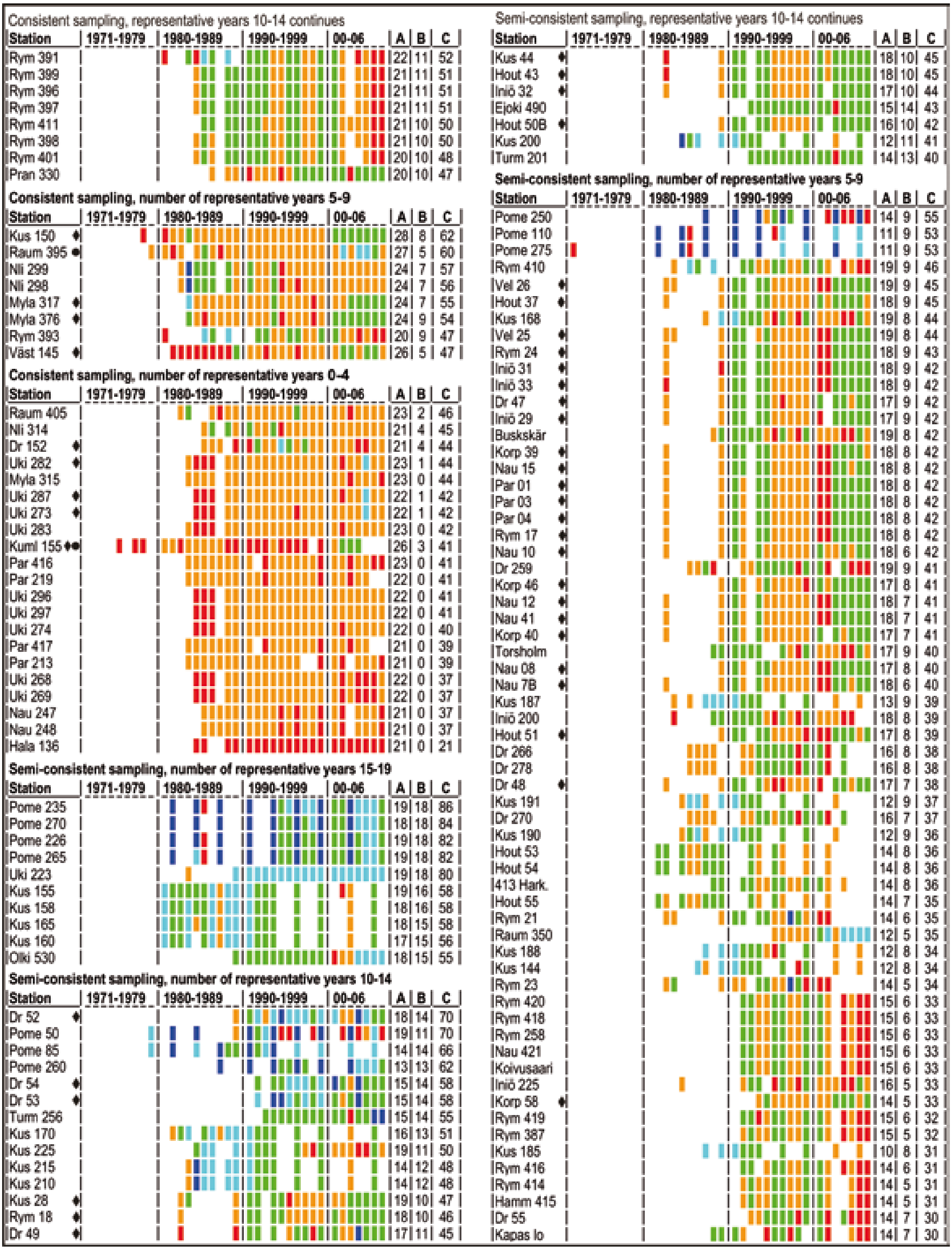
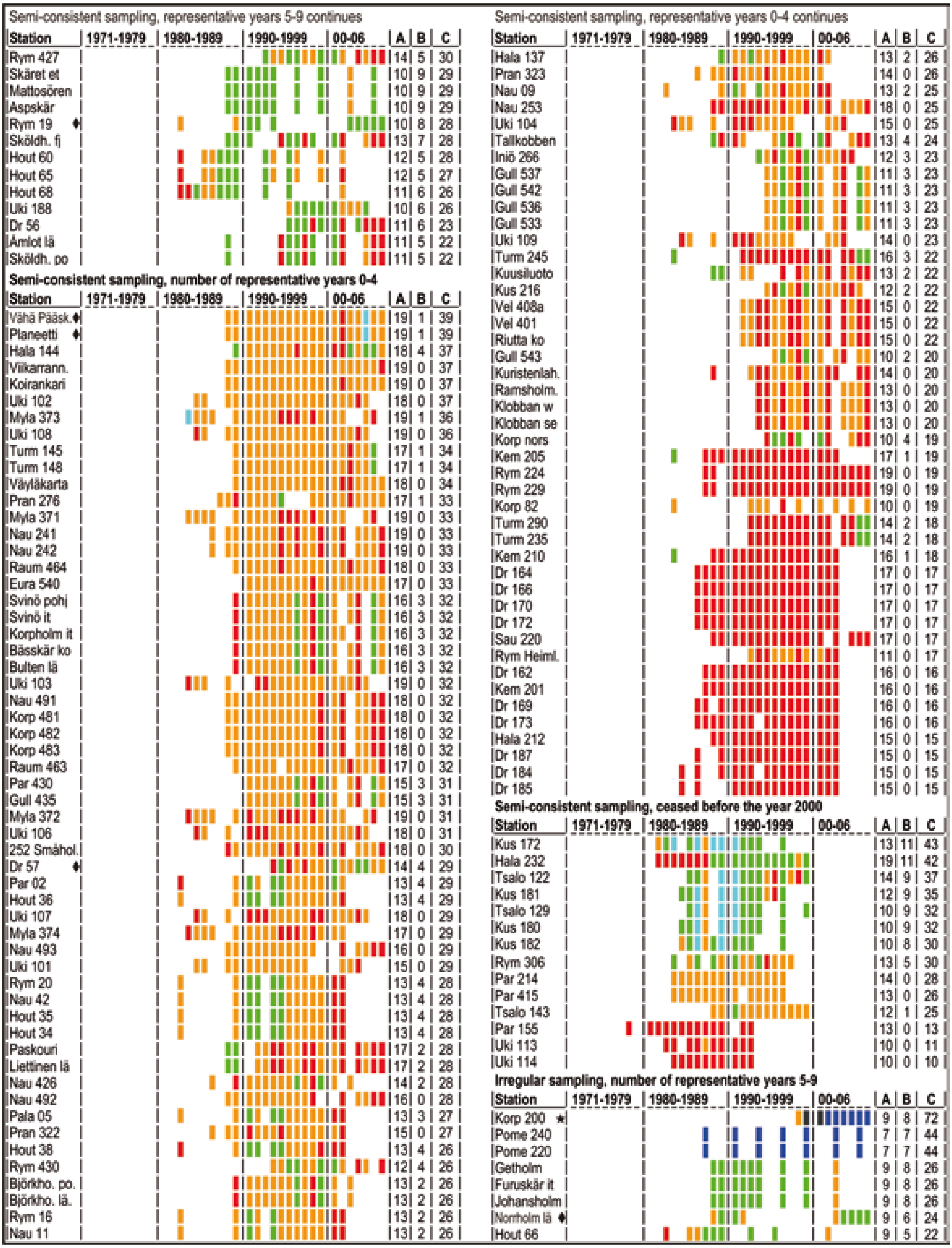
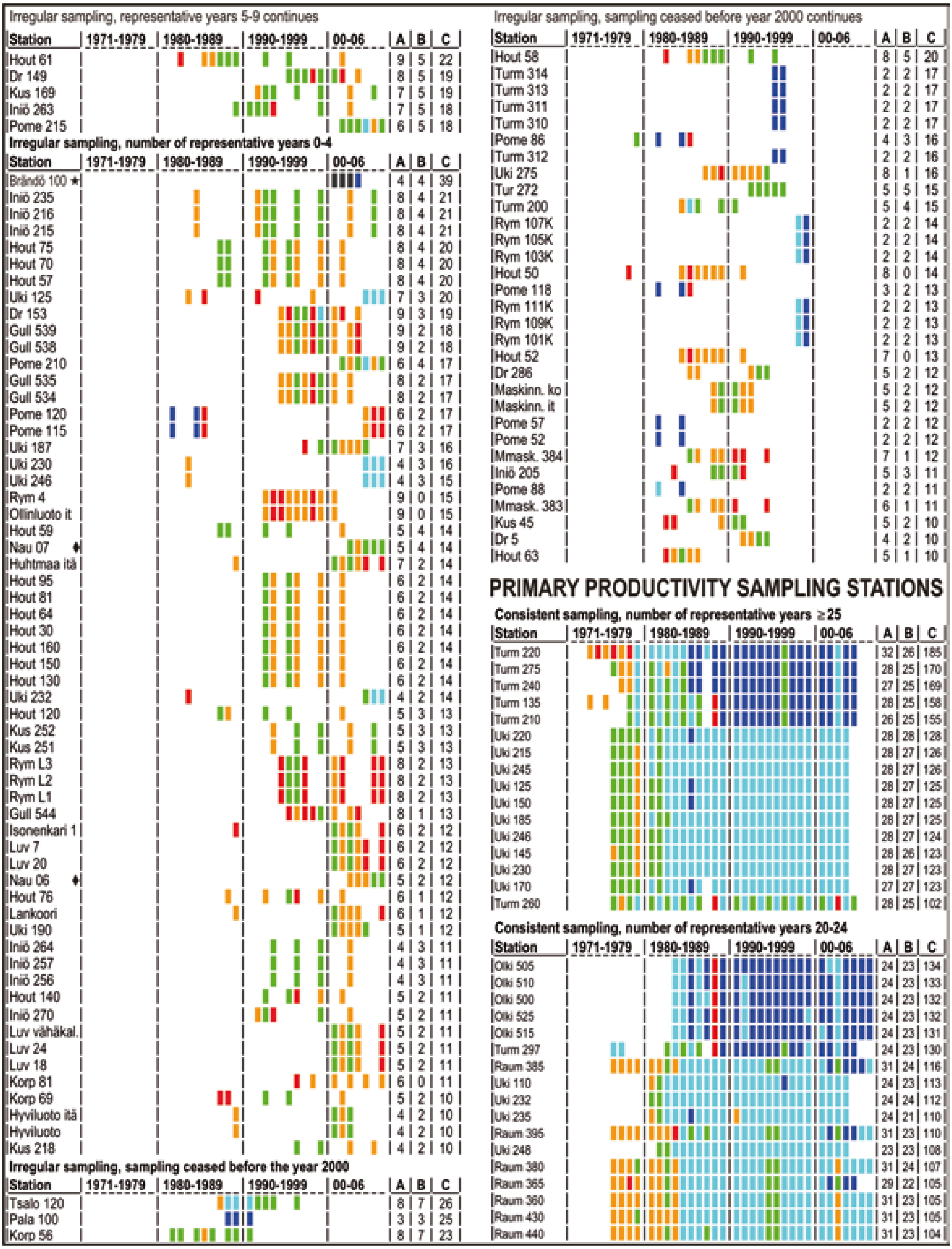
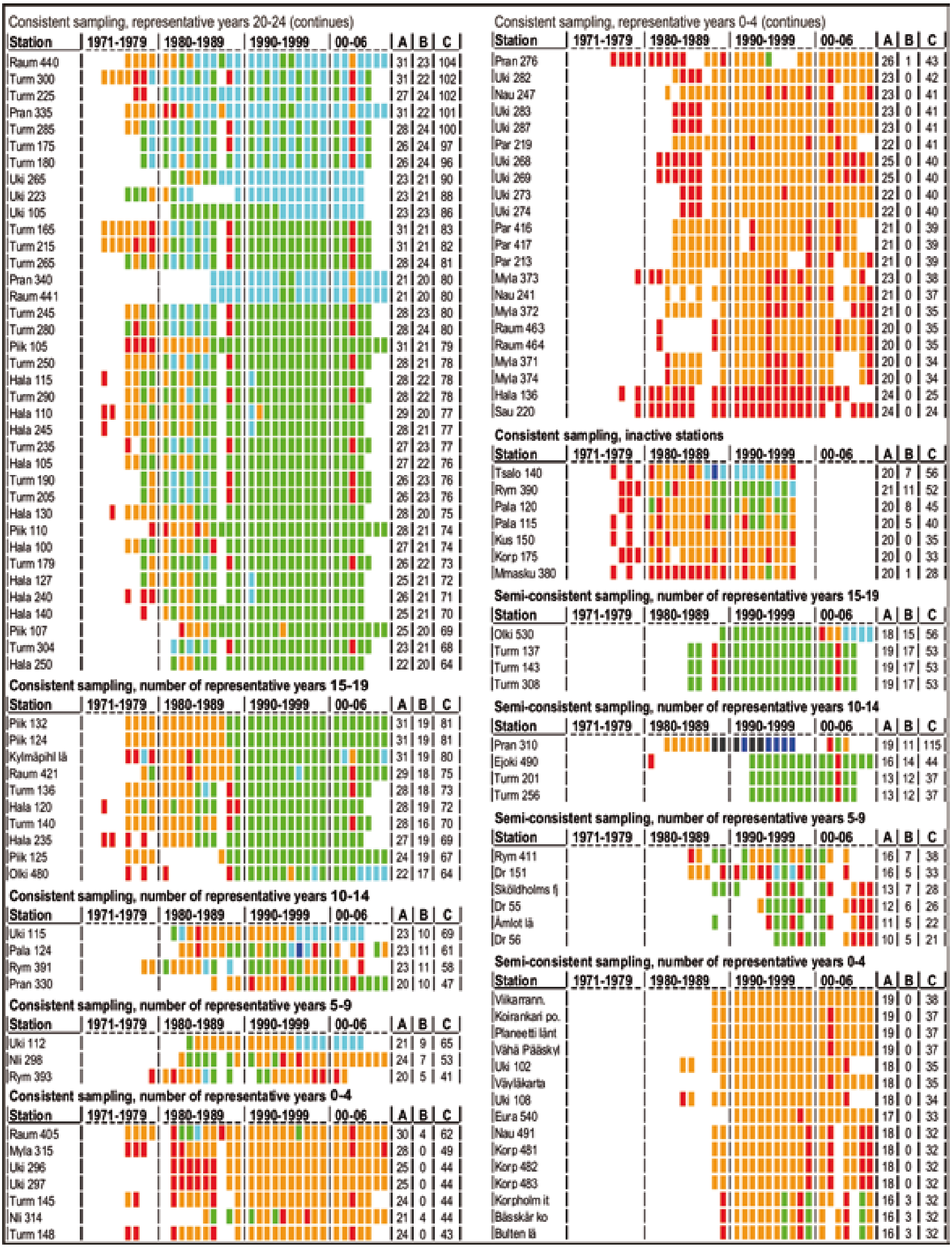
APPENDIX 1. Consistency of water samplings at sampling stations for chlorophyll-*a* (N=469) and primary productivity (N=317) during open water seasons, 1971–2006. Only established stations (total ≥ 10 sampling days) are shown.

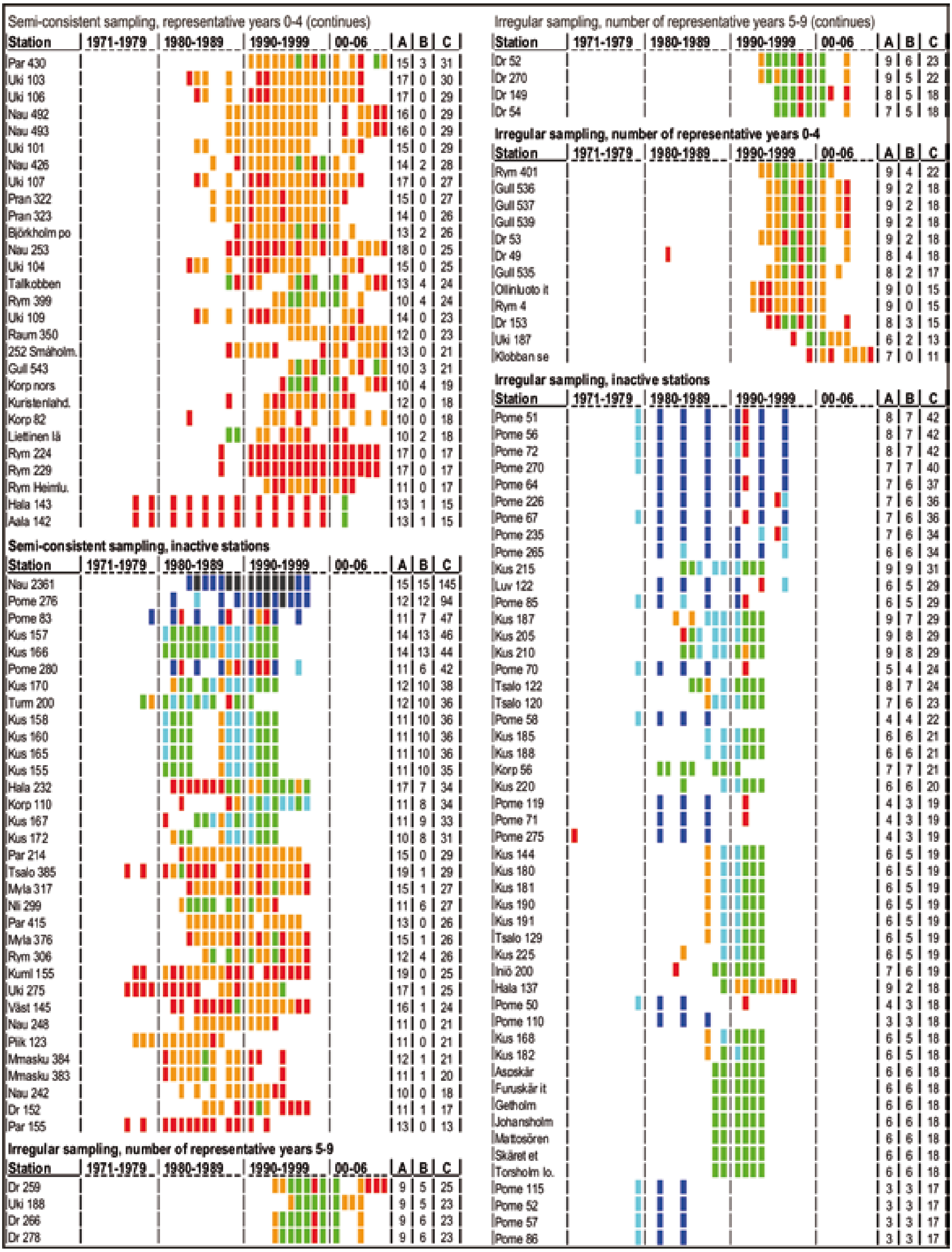


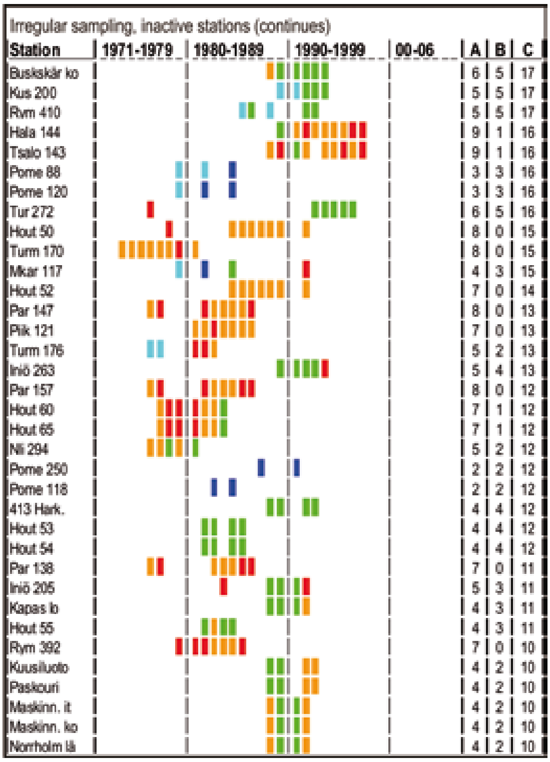

Consistent sampling, representative years 10-14 continues
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Rym 391 22 11 52
Rym 399 21 11 51
Rym 396 21 11 51
Rym 397 21 11 51
Rym 411 21 10 50
Rym 398 21 10 50
Rym 401 20 10 48
Pran 330 20 10 47
Consistent sampling, number of representative years 5-9
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Kus 150 28 8 62
Raum 395 27 5 60
Nli 299 24 7 57
Nli 298 24 7 56
Myla 317 24 7 55
Myla 376 24 9 54
Rym 393 20 9 47
Väst 145 26 5 47
Consistent sampling, number of representative years 0-4
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Raum 405 23 2 46
Nli 314 21 4 45
Dr 152 21 4 44
Uki 282 23 1 44
Myla 315 23 0 44
Uki 287 22 1 42
Uki 273 22 1 42
Uki 283 23 0 42
Kuml 155 26 3 41
Par 416 23 0 41
Par 219 22 0 41
Uki 296 22 0 41
Uki 297 22 0 41
Uki 274 22 0 40
Par 417 21 0 39
Par 213 21 0 39
Uki 268 22 0 37
Uki 269 22 0 37
Nau 247 21 0 37
Nau 248 21 0 37
Hala 136 21 0 21
Semi-consistent sampling, number of representative years 15-19
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Pome 235 19 18 86
Pome 270 18 18 84
Pome 226 19 18 82
Pome 265 19 18 82
Uki 223 19 18 80
Kus 155 19 16 58
Kus 158 18 16 58
Kus 165 18 15 58
Kus 160 17 15 56
Olki 530 18 15 55
Semi-consistent sampling, number of representative years 10-14
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Dr 52 18 14 70
Pome 50 19 11 70
Pome 85 14 14 66
Pome 260 13 13 62
Dr 54 15 14 58
Dr 53 15 14 58
Turm 256 15 14 55
Kus 170 16 13 51
Kus 225 19 11 50
Kus 215 14 12 48
Kus 210 14 12 48
Kus 28 19 10 47
Rym 18 18 10 46
Dr 49 17 11 45
Semi-consistent sampling, representative years 10-14 continues
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Kus 44 18 10 45
Hout 43 18 10 45
Iniö 32 17 10 44
Ejoki 490 15 14 43
Hout 50B 16 10 42
Kus 200 12 11 41
Turm 201 14 13 40
Semi-consistent sampling, number of representative years 5-9
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Pome 250 14 9 55
Pome 110 11 9 53
Pome 275 11 9 53
Rym 410 19 9 46
Vel 26 19 9 45
Hout 37 18 9 45
Kus 168 19 8 44
Vel 25 19 8 44
Rym 24 18 9 43
Iniö 31 18 9 42
Iniö 33 18 9 42
Dr 47 17 9 42
Iniö 29 17 9 42
Buskskär 19 8 42
Korp 39 18 8 42
Nau 15 18 8 42
Par 01 18 8 42
Par 03 18 8 42
Par 04 18 8 42
Rym 17 18 8 42
Nau 10 18 6 42
Dr 259 19 9 41
Korp 46 17 8 41
Nau 12 18 7 41
Nau 41 18 7 41
Korp 40 17 7 41
Torsholm 17 9 40
Nau 08 17 8 40
Nau 7B 18 6 40
Kus 187 13 9 39
Iniö 200 18 8 39
Hout 51 17 8 39
Dr 266 16 8 38
Dr 278 16 8 38
Dr 48 17 7 38
Kus 191 12 9 37
Dr 270 16 7 37
Kus 190 12 9 36
Hout 53 14 8 36
Hout 54 14 8 36
413 Hark. 14 8 36
Hout 55 14 7 35
Rym 21 14 6 35
Raum 350 12 5 35
Kus 188 12 8 34
Kus 144 12 8 34
Rym 23 14 5 34
Rym 420 15 6 33
Rym 418 15 6 33
Rym 258 15 6 33
Nau 421 15 6 33
Koivusaari 15 6 33
Iniö 225 16 5 33
Korp 58 14 5 33
Rym 419 15 6 32
Rym 387 15 5 32
Kus 185 10 8 31
Rym 416 14 6 31
Rym 414 14 5 31
Hamm 415 14 5 31
Dr 55 14 7 30
Kapas lo 14 7 30


Semi-consistent sampling, representative years 5-9 continues
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Rym 427 14 5 30
Skäret et 10 9 29
Mattosören 10 9 29
Aspskär 10 9 29
Rym 19 ♦ 10 8 28
Sköldh. fj 13 7 28
Hout 60 12 5 28
Hout 65 12 5 27
Hout 68 11 6 26
Uki 188 10 6 26
Dr 56 11 6 23
Ämlot lä 11 5 22
Sköldh. po 11 5 22
Semi-consistent sampling, number of representative years 0-4
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Vähä Pääsk. ♦ 19 1 39
Planeetti ♦ 19 1 39
Hala 144 18 4 37
Viikarrann. 19 0 37
Koirankari 19 0 37
Uki 102 18 0 37
Myla 373 19 1 36
Uki 108 19 0 36
Turm 145 17 1 34
Turm 148 17 1 34
Väyläkarta 18 0 34
Pran 276 17 1 33
Myla 371 19 0 33
Nau 241 19 0 33
Nau 242 19 0 33
Raum 464 18 0 33
Eura 540 17 0 33
Svinö pohj 16 3 32
Svinö it 16 3 32
Korpholm it 16 3 32
Bässkär ko 16 3 32
Bulten lä 16 3 32
Uki 103 19 0 32
Nau 491 18 0 32
Korp 481 18 0 32
Korp 482 18 0 32
Korp 483 18 0 32
Raum 463 17 0 32
Par 430 15 3 31
Gull 435 15 3 31
Myla 372 19 0 31
Uki 106 18 0 31
252 Småhol. 18 0 30
Dr 57 ♦ 14 4 29
Par 02 13 4 29
Hout 36 13 4 29
Uki 107 18 0 29
Myla 374 17 0 29
Nau 493 16 0 29
Uki 101 15 0 29
Rym 20 13 4 28
Nau 42 13 4 28
Hout 35 13 4 28
Hout 34 13 4 28
Paskouri 17 2 28
Liettinen lä 17 2 28
Nau 426 14 2 28
Nau 492 16 0 28
Pala 05 13 3 27
Pran 322 15 0 27
Hout 38 13 4 26
Rym 430 12 4 26
Björkho. po. 13 2 26
Björkho. lä. 13 2 26
Rym 16 13 2 26
Nau 11 13 2 26
Semi-consistent sampling, representative years 0-4 continues
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Hala 137 13 2 26
Pran 323 14 0 26
Nau 09 13 2 25
Nau 253 18 0 25
Uki 104 15 0 25
Tallkobben 13 4 24
Iniö 266 12 3 23
Gull 537 11 3 23
Gull 542 11 3 23
Gull 536 11 3 23
Gull 533 11 3 23
Uki 109 14 0 23
Turm 245 16 3 22
Kuusiluoto 13 2 22
Kus 216 12 2 22
Vel 408a 15 0 22
Vel 401 15 0 22
Riutta ko 15 0 22
Gull 543 10 2 20
Kuristenlah. 14 0 20
Ramsholm. 13 0 20
Klobban w 13 0 20
Klobban se 13 0 20
Korp nors 10 4 19
Kem 205 17 1 19
Rym 224 19 0 19
Rym 229 19 0 19
Korp 82 10 0 19
Turm 290 14 2 18
Turm 235 14 2 18
Kem 210 16 1 18
Dr 164 17 0 17
Dr 166 17 0 17
Dr 170 17 0 17
Dr 172 17 0 17
Sau 220 17 0 17
Rym Heiml. 11 0 17
Dr 162 16 0 16
Kem 201 16 0 16
Dr 169 16 0 16
Dr 173 16 0 16
Hala 212 15 0 15
Dr 187 15 0 15
Dr 184 15 0 15
Dr 185 15 0 15
Semi-consistent sampling, ceased before the year 2000
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Kus 172 13 11 43
Hala 232 19 11 42
Tsalo 122 14 9 37
Kus 181 12 9 35
Tsalo 129 10 9 32
Kus 180 10 9 32
Kus 182 10 8 30
Rym 306 13 5 30
Par 214 14 0 28
Par 415 13 0 26
Tsalo 143 12 1 25
Par 155 13 0 13
Uki 113 10 0 11
Uki 114 10 0 10
Irregular sampling, number of representative years 5-9
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Korp 200 ★ 9 8 72
Pome 240 7 7 44
Pome 220 7 7 44
Getholm 9 8 26
Furuskär it 9 8 26
Johansholm 9 8 26
Norrholm lä ♦ 9 6 24
Hout 66 9 5 22


Irregular sampling, representative years 5-9 continues
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Hout 61 | 9 | 5 | 22
Dr 149 | 8 | 5 | 19
Kus 169 | 7 | 5 | 19
Iniö 263 | 7 | 5 | 18
Pome 215 | 6 | 5 | 18
Irregular sampling, number of representative years 0-4
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Brändö 100 ★ | 4 | 4 | 39
Iniö 235 | 8 | 4 | 21
Iniö 216 | 8 | 4 | 21
Iniö 215 | 8 | 4 | 21
Hout 75 | 8 | 4 | 20
Hout 70 | 8 | 4 | 20
Hout 57 | 8 | 4 | 20
Uki 125 | 7 | 3 | 20
Dr 153 | 9 | 3 | 19
Gull 539 | 9 | 2 | 18
Gull 538 | 9 | 2 | 18
Pome 210 | 6 | 4 | 17
Gull 535 | 8 | 2 | 17
Gull 534 | 8 | 2 | 17
Pome 120 | 6 | 2 | 17
Pome 115 | 6 | 2 | 17
Uki 187 | 7 | 3 | 16
Uki 230 | 4 | 3 | 16
Uki 246 | 4 | 3 | 15
Rym 4 | 9 | 0 | 15
Ollinluoto it | 9 | 0 | 15
Hout 59 | 5 | 4 | 14
Nau 07 ♦ | 5 | 4 | 14
Huhtmaa itä | 7 | 2 | 14
Hout 95 | 6 | 2 | 14
Hout 81 | 6 | 2 | 14
Hout 64 | 6 | 2 | 14
Hout 30 | 6 | 2 | 14
Hout 160 | 6 | 2 | 14
Hout 150 | 6 | 2 | 14
Hout 130 | 6 | 2 | 14
Uki 232 | 4 | 2 | 14
Hout 120 | 5 | 3 | 13
Kus 252 | 5 | 3 | 13
Kus 251 | 5 | 3 | 13
Rym L3 | 8 | 2 | 13
Rym L2 | 8 | 2 | 13
Rym L1 | 8 | 2 | 13
Gull 544 | 8 | 1 | 13
Isonenkari 1 | 6 | 2 | 12
Luv 7 | 6 | 2 | 12
Luv 20 | 6 | 2 | 12
Nau 06 ♦ | 5 | 2 | 12
Hout 76 | 6 | 1 | 12
Lankoori | 6 | 1 | 12
Uki 190 | 5 | 1 | 12
Iniö 264 | 4 | 3 | 11
Iniö 257 | 4 | 3 | 11
Iniö 256 | 4 | 3 | 11
Hout 140 | 5 | 2 | 11
Iniö 270 | 5 | 2 | 11
Luv vähäkal. | 5 | 2 | 11
Luv 24 | 5 | 2 | 11
Luv 18 | 5 | 2 | 11
Korp 81 | 6 | 0 | 11
Korp 69 | 5 | 2 | 10
Hyviluoto itä | 4 | 2 | 10
Hyviluoto | 4 | 2 | 10
Kus 218 | 4 | 2 | 10
Irregular sampling, sampling ceased before the year 2000
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Tsalo 120 | 8 | 7 | 26
Pala 100 | 3 | 3 | 25
Korp 56 | 8 | 7 | 23
Irregular sampling, sampling ceased before year 2000 continues
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Hout 58 | 8 | 5 | 20
Turm 314 | 2 | 2 | 17
Turm 313 | 2 | 2 | 17
Turm 311 | 2 | 2 | 17
Turm 310 | 2 | 2 | 17
Pome 86 | 4 | 3 | 16
Turm 312 | 2 | 2 | 16
Uki 275 | 8 | 1 | 16
Tur 272 | 5 | 5 | 15
Turm 200 | 5 | 4 | 15
Rym 107K | 2 | 2 | 14
Rym 105K | 2 | 2 | 14
Rym 103K | 2 | 2 | 14
Hout 50 | 8 | 0 | 14
Pome 118 | 3 | 2 | 13
Rym 111K | 2 | 2 | 13
Rym 109K | 2 | 2 | 13
Rym 101K | 2 | 2 | 13
Hout 52 | 7 | 0 | 13
Dr 286 | 5 | 2 | 12
Maskinn. ko | 5 | 2 | 12
Maskinn. it | 5 | 2 | 12
Pome 57 | 2 | 2 | 12
Pome 52 | 2 | 2 | 12
Mmask. 384 | 7 | 1 | 12
Iniö 205 | 5 | 3 | 11
Pome 88 | 2 | 2 | 11
Mmask. 383 | 6 | 1 | 11
Kus 45 | 5 | 2 | 10
Dr 5 | 4 | 2 | 10
Hout 63 | 5 | 1 | 10
PRIMARY PRODUCTIVITY SAMPLING STATIONS
Consistent sampling, number of representative years ≥25
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Turm 220 | 32 | 26 | 185
Turm 275 | 28 | 25 | 170
Turm 240 | 27 | 25 | 169
Turm 135 | 28 | 25 | 158
Turm 210 | 26 | 25 | 155
Uki 220 | 28 | 28 | 128
Uki 215 | 28 | 27 | 126
Uki 245 | 28 | 27 | 126
Uki 125 | 28 | 27 | 125
Uki 150 | 28 | 27 | 125
Uki 185 | 28 | 27 | 125
Uki 246 | 28 | 27 | 124
Uki 145 | 28 | 26 | 123
Uki 230 | 28 | 27 | 123
Uki 170 | 27 | 27 | 123
Turm 260 | 28 | 25 | 102
Consistent sampling, number of representative years 20-24
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Olki 505 | 24 | 23 | 134
Olki 510 | 24 | 23 | 133
Olki 500 | 24 | 23 | 132
Olki 525 | 24 | 23 | 132
Olki 515 | 24 | 23 | 131
Turm 297 | 24 | 23 | 130
Raum 385 | 31 | 24 | 116
Uki 110 | 24 | 23 | 113
Uki 232 | 24 | 24 | 112
Uki 235 | 24 | 21 | 110
Raum 395 | 31 | 23 | 110
Uki 248 | 23 | 23 | 108
Raum 380 | 31 | 24 | 107
Raum 365 | 29 | 22 | 105
Raum 360 | 31 | 23 | 105
Raum 430 | 31 | 23 | 105
Raum 440 | 31 | 23 | 104


Consistent sampling, representative years 20-24 (continues)
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Raum 440 31 23 104
Turm 300 31 22 102
Turm 225 27 24 102
Pran 335 31 22 101
Turm 285 28 24 100
Turm 175 26 24 97
Turm 180 26 24 96
Uki 265 23 21 90
Uki 223 23 21 88
Uki 105 23 23 86
Turm 165 31 21 83
Turm 215 31 21 82
Turm 265 28 24 81
Pran 340 21 20 80
Raum 441 21 20 80
Turm 245 28 23 80
Turm 280 28 24 80
Piik 105 31 21 79
Turm 250 28 21 78
Hala 115 28 22 78
Turm 290 28 22 78
Hala 110 29 20 77
Hala 245 28 21 77
Turm 235 27 23 77
Hala 105 27 22 76
Turm 190 26 23 76
Turm 205 26 23 76
Hala 130 28 20 75
Piik 110 28 21 74
Hala 100 27 21 74
Turm 179 26 22 73
Hala 127 25 21 72
Hala 240 26 21 71
Hala 140 25 21 70
Piik 107 25 20 69
Turm 304 23 21 68
Hala 250 22 20 64
Consistent sampling, number of representative years 15-19
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Piik 132 31 19 81
Piik 124 31 19 81
Kylmäpihl lä 31 19 80
Raum 421 29 18 75
Turm 136 28 18 73
Hala 120 28 19 72
Turm 140 28 16 70
Hala 235 27 19 69
Piik 125 24 19 67
Olki 480 22 17 64
Consistent sampling, number of representative years 10-14
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Uki 115 23 10 69
Pala 124 23 11 61
Rym 391 23 11 58
Pran 330 20 10 47
Consistent sampling, number of representative years 5-9
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Uki 112 21 9 65
Nli 298 24 7 53
Rym 393 20 5 41
Consistent sampling, number of representative years 0-4
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Raum 405 30 4 62
Myla 315 28 0 49
Uki 296 25 0 44
Uki 297 25 0 44
Turm 145 24 0 44
Nli 314 21 4 44
Turm 148 24 0 43
Consistent sampling, representative years 0-4 (continues)
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Pran 276 26 1 43
Uki 282 23 0 42
Nau 247 23 0 41
Uki 283 23 0 41
Uki 287 23 0 41
Par 219 22 0 41
Uki 268 25 0 40
Uki 269 25 0 40
Uki 273 22 0 40
Uki 274 22 0 40
Par 416 21 0 39
Par 417 21 0 39
Par 213 21 0 39
Myla 373 23 0 38
Nau 241 21 0 37
Myla 372 21 0 35
Raum 463 20 0 35
Raum 464 20 0 35
Myla 371 20 0 34
Myla 374 20 0 34
Hala 136 24 0 25
Sau 220 24 0 24
Consistent sampling, inactive stations
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Tsalo 140 20 7 56
Rym 390 21 11 52
Pala 120 20 8 45
Pala 115 20 5 40
Kus 150 20 0 35
Korp 175 20 0 33
Mmasku 380 20 1 28
Semi-consistent sampling, number of representative years 15-19
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Olki 530 18 15 56
Turm 137 19 17 53
Turm 143 19 17 53
Turm 308 19 17 53
Semi-consistent sampling, number of representative years 10-14
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Pran 310 19 11 115
Ejoki 490 16 14 44
Turm 201 13 12 37
Turm 256 13 12 37
Semi-consistent sampling, number of representative years 5-9
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Rym 411 16 7 38
Dr 151 16 5 33
Sköldholms fj 13 7 28
Dr 55 12 6 26
Ämlot lä 11 5 22
Dr 56 10 5 21
Semi-consistent sampling, number of representative years 0-4
Station 1971-1979 1980-1989 1990-1999 00-06 A B C
Viikarrann. 19 0 38
Koirankari po. 19 0 37
Planeetti länt 19 0 37
Vähä Pääskyl 19 0 37
Uki 102 18 0 35
Väyläkarta 18 0 35
Uki 108 18 0 34
Eura 540 17 0 33
Nau 491 18 0 32
Korp 481 18 0 32
Korp 482 18 0 32
Korp 483 18 0 32
Korpholm it 16 3 32
Bässkär ko 16 3 32
Bulten lä 16 3 32


Semi-consistent sampling, representative years 0-4 (continues)
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Par 430 15 3 31
Uki 103 17 0 30
Uki 106 17 0 29
Nau 492 16 0 29
Nau 493 16 0 29
Uki 101 15 0 29
Nau 426 14 2 28
Uki 107 17 0 27
Pran 322 15 0 27
Pran 323 14 0 26
Björkholm po 13 2 26
Nau 253 18 0 25
Uki 104 15 0 25
Talkobben 13 4 24
Rym 399 10 4 24
Uki 109 14 0 23
Raum 350 12 0 23
252 Småholm. 13 0 21
Gull 543 10 3 21
Korp nors 10 4 19
Kuristenlahd. 12 0 18
Korp 82 10 0 18
Liettinen lä 10 2 18
Rym 224 17 0 17
Rym 229 17 0 17
Rym Heimlu. 11 0 17
Hala 143 13 1 15
Aala 142 13 1 15
Semi-consistent sampling, inactive stations
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Nau 2361 15 15 145
Pome 276 12 12 94
Pome 83 11 7 47
Kus 157 14 13 46
Kus 166 14 13 44
Pome 280 11 6 42
Kus 170 12 10 38
Turn 200 12 10 36
Kus 158 11 10 36
Kus 160 11 10 36
Kus 165 11 10 36
Kus 155 11 10 35
Hala 232 17 7 34
Korp 110 11 8 34
Kus 167 11 9 33
Kus 172 10 8 31
Par 214 15 0 29
Tsalo 385 19 1 29
Myla 317 15 1 27
Nii 299 11 6 27
Par 415 13 0 26
Myla 376 15 1 26
Rym 306 12 4 26
Kuml 155 19 0 25
Uki 275 17 1 25
Väst 145 16 1 24
Nau 248 11 0 21
Piik 123 11 0 21
Mmasku 384 12 1 21
Mmasku 383 11 1 20
Nau 242 10 0 18
Dr 152 11 1 17
Par 155 13 0 13
Irregular sampling, number of representative years 5-9
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Dr 259 9 5 25
Uki 188 9 5 23
Dr 266 9 6 23
Dr 278 9 6 23
Irregular sampling, number of representative years 5-9 (continues)
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Dr 52 9 6 23
Dr 270 9 5 22
Dr 149 8 5 18
Dr 54 7 5 18
Irregular sampling, number of representative years 0-4
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Rym 401 9 4 22
Gull 536 9 2 18
Gull 537 9 2 18
Gull 539 9 2 18
Dr 53 9 2 18
Dr 49 8 4 18
Gull 535 8 2 17
Ollinluoto it 9 0 15
Rym 4 9 0 15
Dr 153 8 3 15
Uki 187 6 2 13
Klobban se 7 0 11
Irregular sampling, inactive stations
Station | 1971-1979 | 1980-1989 | 1990-1999 | 00-06 | A | B | C
Pome 51 8 7 42
Pome 56 8 7 42
Pome 72 8 7 42
Pome 270 7 7 40
Pome 64 7 6 37
Pome 226 7 6 36
Pome 67 7 6 36
Pome 235 7 6 34
Pome 265 6 6 34
Kus 215 9 9 31
Luv 122 6 5 29
Pome 85 6 5 29
Kus 187 9 7 29
Kus 205 9 8 29
Kus 210 9 8 29
Pome 70 5 4 24
Tsalo 122 8 7 24
Tsalo 120 7 6 23
Pome 58 4 4 22
Kus 185 6 6 21
Kus 188 6 6 21
Korp 56 7 7 21
Kus 220 6 6 20
Pome 119 4 3 19
Pome 71 4 3 19
Pome 275 4 3 19
Kus 144 6 5 19
Kus 180 6 5 19
Kus 181 6 5 19
Kus 190 6 5 19
Kus 191 6 5 19
Tsalo 129 6 5 19
Kus 225 6 5 19
Iniö 200 7 6 19
Hala 137 9 2 18
Pome 50 4 3 18
Pome 110 3 3 18
Kus 168 6 5 18
Kus 182 6 5 18
Aspskär 6 6 18
Furuskär it 6 6 18
Getholm 6 6 18
Johansholm 6 6 18
Mattosören 6 6 18
Skäret et 6 6 18
Torsholm lo. 6 6 18
Pome 115 3 3 17
Pome 52 3 3 17
Pome 57 3 3 17
Pome 86 3 3 17


Irregular sampling, inactive stations (continues)
Station
1971-1979
1980-1989
1990-1999
00-06
A
B
C
Buskskär ko 6 5 17
Kus 200 5 5 17
Rvm 410 5 5 17
Hala 144 9 1 16
Tsalo 143 9 1 16
Pome 88 3 3 16
Pome 120 3 3 16
Tur 272 6 5 16
Hout 50 8 0 15
Turm 170 8 0 15
Mkar 117 4 3 15
Hout 52 7 0 14
Par 147 8 0 13
Piik 121 7 0 13
Turm 176 5 2 13
Iniö 263 5 4 13
Par 157 8 0 12
Hout 60 7 1 12
Hout 65 7 1 12
Nli 294 5 2 12
Pome 250 2 2 12
Pome 118 2 2 12
413 Hark. 4 4 12
Hout 53 4 4 12
Hout 54 4 4 12
Par 138 7 0 11
Iniö 205 5 3 11
Kapas lo 4 3 11
Hout 55 4 3 11
Rym 392 7 0 10
Kuusiluoto 4 2 10
Paskouri 4 2 10
Maskinn. it 4 2 10
Maskinn. ko 4 2 10
Norrholm lä 4 2 10