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Design of Norwegian Monitoring Network for Reference Sites

Draft report

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Sammendrag

The present report is a draft proposal for the design of a monitoring programme for reference sites for all surface water categories compatible with the requirements in the EU Water Framework Directive. To be completed in the final report.

Fire norske emneord	Fire engelske emneord
1. Overvåking	1. Monitoring
2. Referanselokaliteter	2. Reference sites
3. EUs Rammedirektiv for Vann	3. EU Water Framework Directive
4. Innsjøer, elver, kystvann	4. Lakes, rivers, coastal waters

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Design of Norwegian Monitoring Network for Reference Sites

Draft report, 23rd February 2005

Forord

This report presents a proposal for a WFD-compatible design of a monitoring programme for Norwegian reference sites for lakes, rivers and coastal waters. The present version is a first draft which has not been subject to quality assurance. The following authors are responsible for different parts of the report:

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Sammendrag

Norsk sammendrag vil bli skrevet i den endelige rapporten

Summary

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Summary will be presented in final version of report.

1. Introduction

1.1 Background

The EU Water Framework Directive requires the establishment of a network of reference sites for monitoring of reference conditions for all types of water bodies present within the territories of different countries. This applies to all categories of surface waters. The monitoring of reference sites should provide the numerical basis for setting reference values and confidence intervals for all the elements listed in Annex V of the Directive. As such the reference monitoring network is crucial to enable classification of the ecological status of impacted sites, measured as deviations from these reference values.

1.2 Objective

The objective of the present report is to propose a design for the Norwegian Reference Sites Monitoring Network for rivers, lakes and coastal waters, which ensures the establishment of type-specific reference values with sufficient precision for all biological and supporting physico-chemical elements required in the Annex V of the Directive.

1.3 Work process

The work process applied in this project has been divided in four phases:

- to collect data from as many reference sites as possible for each surface water category
- to gather experts for the different categories in a workshop to discuss the selection of water body types, the number of sites per type, the selection of elements to be included and the sampling frequency needed
- to perform statistical analyses of the data sets in order to recommend the optimal and minimal number of sites, elements and frequencies (done partly before, partly during, and partly after the workshop)
- to draft a report presenting the proposal for the design of the Reference Network

This draft will be revised according to comments from the Norwegian national authorities responsible for WFD monitoring.

The final report will be used as a basis for further collaboration with the Nordic countries in an attempt to obtain a common Nordic design for a Reference Network, and reduce the number of sites required in each country for common water body types.

2. Lakes

2.1 Methods

2.1.1 Datasets on potential reference sites

The starting point for selection of reference lakes was the list of lakes presented in Table B1 in the first typology report for lakes and rivers (Lyche-Lyche Solheim et al. 2003). The results compiled from the characterisation of water bodies preformed in 2004 (NVE pers. comm.) for these 500 lakes, have been used to exclude lakes from this list that are either acidified, heavily modified, or classified as "at risk" or "possibly at risk" of failing the WFD objective of good status. Also lakes without typology data have been excluded. The latter were mostly small lakes < 0.5 km^2. Typology data for those small lakes can be estimated from the river reach, which is identified as the water body to which the small lakes belong, but this has not been possible within the time and budget constraints of this project.

The remaining lakes have all been indicated to be "clearly not at risk" in the characterisation projects, and thus should be considered as true reference lakes, untill new monitoring data prove otherwise. Since the number of remaining lakes have shrunk to 134 lakes, additional lakes will most probably be needed for many lake types in many ecoregions (see chapter 3.1), in order to obtain acceptable statistical power (see Chapter 3.1.4 below).

Additional reference lakes can be found in the next stage of the project (if funding is provided) from the > 3000 lakes indicated to be "not at risk" in the characterisation projects (Stalsberg, NVE pers. comm..). NVE has not had the capacity to provide this list including typology data for the present stage of this reference network project. However, the large number of lakes indicated to be "not at risk" should enable the future selection of sufficient number of lakes for many lake types.

2.1.2 Chemical and biological datasets used for statistical testing / recommendations

Analyses of spatial variation in chemical parameters (tot P) were based on the dataset "RESA". The RESA data are from a national lake survey in Norway carried out in 1995. Alltogether 1500 lakes, not influenced by local sources, were sampled. 1000 of those were selected by a size-stratified statistically representative sampling scheme in order to get a representativ selection of lakes . Another 500 lakes were included as a follow up of a previos (1986) lake survey in order to follow trends in water chemsitry. Main chemical composition was analysed in all lakes. Lakes in the 6 northernmost counties are selected as reference sites, because this area is least affected by acidification.

Analyses of spatial variation in biological parameters (total algal biomass, proportion cyanobacteria, proportion chrysophytes) were based on the dataset "EUREGI". These data are from the Norwegian eutrophication survey 1988-2000, reported in Lyche Solheim et al. 2004. The data consist of ca. 2530 samples from 400 lakes, which are selected to represent a broad gradient of anthropogenic pressure. Algae are mostly identified to species level for all samples. Biological elements used for the statistical testing are total algal biomass, proportion cyanobacteria (tolerant to eutrophication) and proportion chrysophytes (sensitive to eutrophication). Reference sites are selected by expert judgement (Brettum pers. comm.).

Tabell 1. Number of reference lakes per lakes type for the datasets EUREGI and RESA.

Lake type	EUREGI	RESA
Low or very low alkalinity, clear	132	365
Low alkalinity, humic	28	60
Moderate alkalinity, clear	28	61
Moderate alkalinity, humic	4	18
Total	192	504

Analyses of temporal variation in algal biomass were based on a 14-years time series from Lake Atnsjøen, which is an ultraoligotroph reference lake used for monitoring of reference conditions.

Analyses on spatial variance in fish populations were based on a dataset of trout populations from Norwegian lakes. Abundances were recorded as Catch per Unit Effort (CPUE) in numbers of individuals. All lakes that were regulated (Reg=2) were excluded from the dataset which left us with 154 lakes. The dataset included both lakes which are unaffected by regulation (Reg=0) and lakes where the water flow but not the water level is affected by regulation (Reg=1). Lakes with introduced fish were also included.

Analyses on temporal variance in fish populations were based on time series (1985-2004) on trout and charr from Lake Atnsjøen.

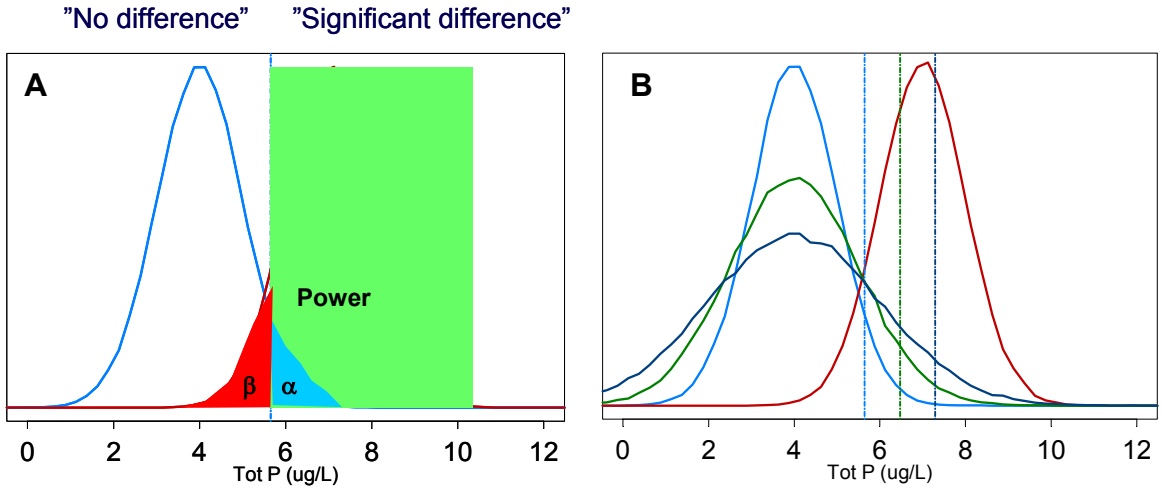
Analyses on spatial variance in microcrustacean communities (Cladocera + Copepoda) were based on a dataset of 39 boreal, low alkalinity, clear lakes in Central Norway. The dataset include only present/absent data (species present). All lakes are expected to be non-impacted but the ecological status of the lakes has not been validated against the results from the Characterization projects (Characterisation of Norwegian water bodies).

Assessment of temporal variance in microcrustacean communities was based on the dataset from five non-impacted or only slightly impacted sites in the monitoring program on acidification in Norwegian lakes. The lakes represent the lake types very low alkalinity, clear (boreal and highland) as well as low alkalinity, organic (boreal). Yearly data on species composition exist for five to seven years in the period 1997-2003.

2.1.3 Brief description of methods used for statistical testing

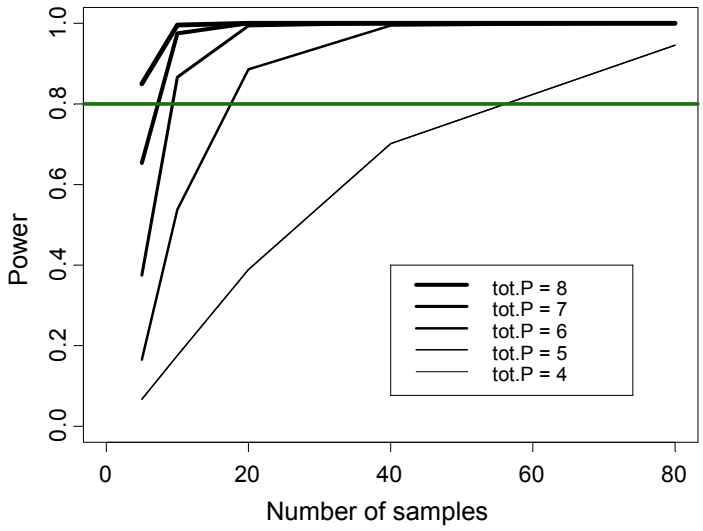
Background: variance components and statistical power

The aim is to assess the number of sites per type, sampling frequency per year, and years of observation that is high enough to characterise the natural variation within and between reference lakes. Information about natural variation within and/or between reference lakes is necessary for performing statistical power analyses, i.e. for assessing the probability for (1) detecting differences between possibly impacted lakes and reference lakes and (2) for detecting a temporal trend within a reference site. **Figur 1** illustrates this principle: a higher variation in total P among reference sites will give a lower probability to detect a difference in total P between an impacted site and the reference sites. Hence, if we underestimate the natural variation, we will overestimate our ability to detect a certain difference/trend.



Figur 1. (**A**) Calculation of power. The blue and red curves represent histograms of total P values from reference and impacted sites, respectively. The selected significance level (normally $\alpha = 0.05$) determines the critical value of parameter (vertical line). The signficance level is the probability for falsely detecting a difference, and corresponds to the proportion of reference sites Tot P values above the critical value. The power is probability for correctly detecting a difference, and corresponds to the proportion of impacted sites Tot P values above the critical value. (**B**) Higher variation in reference values will give a flatter distribution, and move the critical value further to the right, which will decrease the power. In this case, increasing the standard deviation from 1.0 to 2.0 reduces the power from 91% to 39%.

Statistical power also increases with the number of samples, as well as with the magnitude of the difference/trend to be detected (see **Figur 2**). By convention, a statistical power above 80% is desired.



Figur 2. Illustration of statistical power analyses: probability for detecting a difference in total P from 2.8 µg/L (mean for reference sites) to 4 - 8 µg/L. Significance level is 5%. Power increases with number of samples and with the difference to be detected.

Variance components can be separated into 4 categories:

1. Sampling-related variance.

(i) “Pure” randomness in the data collection; “sampling error” (the smaller the sample is the greater effect). (ii) Systematic error; “sampling bias”. (iii) Varying sampling effort. Must be corrected or standardized.

2. Spatial variance
   (i) Geographical regions; local / regional climatic conditions. (ii) Type of habitat (water chemistry etc). (iii) Differences in community size or limitation.
3. Temporal variance
   (i) Trends or cyclic dynamics must be accounted for. (ii) Seasonal variance: community composition will vary during the season. Time of collection important for species with short life spans. (iii) Year to year variance; environmental variance.
4. ”Extra” variance; unnatural changes in the measured parameter due to human influence on habitat quality.

If information on sampling variances is missing, the estimates for spatial and temporal variances will be confounded with sampling uncertainty.

In order to obtain good variance estimates, we need considerably more observations than when estimating averages, especially if the distribution is skewed.

1. A standardized design is required so that effort, method etc. are kept constant. The random error can be estimated from parallel samples.
2. Spatial variance between localities of the same type, and between averages of localities of different types can be estimated. Assume additive variances in order to separate sampling and spatial variance.
3. The environmental variance is estimated by following the same location over time. Different species and water-body types can have different variances. If year-to-year is calculated directly trends will be included in estimate; trends should also be estimated separately. Different approaches can be used to estimate environmental variance.

Number of sites per lake type

Chemical parameteres and phytoplankton

Increasing the number of sites per lake type will increase the probability for detecting a difference between an impacted site and a reference site. However, power analyses cannot be used directly to select the number of reference sites at this stage, because this requires information about how large difference should be detected between reference and impact sites, and about the natural variation within impacted sites. We have therefore focused on characterising the natural variation of reference sites: how does the standard deviation (i.e. our estimates of the natural variation) depend on the number of sites? We have used the following procedure, for each lake type and for different chemical elements (pH, ANC, TotP) and biological elements (total algal biomass, proportion cyanobacteria, proprtion chrysophytes):

1) Select a range of number of reference sites (e.g. n = 5,10,15,.. 50)
2) For each n, draw n reference sites randomly from the pool of reference sites
3) Calculate mean and standard deviation
4) Repeat 2) and 3) 250 times
5) Calculate mean and 95% quantiles for the 250 means and standard deviations.

The quantile curves can represent a 95% confidence interval, and indicates how increasing the number of sites increases our confidence about the estimates of natural variation. This will in turn increases our ability to correctly detect differences between reference sites and impacted sites.

Fish
Initially we used scatterplot to check if 1) fish introduction lake-size had any systematic effect on CPUE. We concluded that there were no systematic effects, i.e lakes with fish introductions were included in the further analyses and we did not correct for lake size. One-way ANOVA and two-sample t-test was used to test for differences in mean number of fish caught between Regulation=1 and Regulation=0 lakes, between lakes from different eco-regions (not considering the altitude) and between lakes from different altitude categories (not considering the eco-regions). To test if there were differences between types (altitude) within each region we used a General Linear Model. The results indicate that there were no significant differences in CPUE between lakes with no regulation (0) and lakes with only upstream regulations (1). The two datasets were pooled in the further analyses.

As an illustration how different variance components can be quantified, we decomposed the total variance into "within region" and "between regions". Simplifying assumption will be that the "within region" variance is constant, i.e. equal for all regions, and that the different variance components are independent. We also assume that the means from each region are "random observations from some distribution". Let:

$$s^2_{bRm} = s^2_{bR} + \frac{1}{m}\sum_{i=1}^{m}\frac{s^2_{bl_i}}{n_i}$$

where is the variance "between the Region means" (bRm), the actual variance between the regions and the last term express the weighted effect of the "between Lakes variance" for each Region (m = number of Regions, = variance between Lakes in Region i, ni=# Lakes in Region i). With words; the variance between the calculated means of the regions are a sum of the variance between the "real" means and the weighted standard errors of the calculated means.

Microcrustaceans
Spatial variation in species composition was analysed by an ordination technique; Detrended Correspondence Analysis. The resulting site scores serve as a diversity index based on the species composition of the sites, and differences in the site scores indicate differences in species composition between the sites. Initially we have calculated the variance as % CV based on the site scores along the first DCA axis (not describing the total variance).

Timing and number of observations per year

Phytoplankton
A higher number of observations per year gives a better precision, which is a measure of how the true values are estimated by sampling. A higher precision will increase the probability for correctly detecting a difference or trend. The precision is supposed to reflect only the sampling variation (which should be minimized), not the natural variation (which cannot be reduced). Higher frequency of samples per year also enables us to better account for seasonal variation. Analyses of phytoplankton from Gulf of Finland (J. Carstensen, pers. comm.) show that the required number of chlorophyll samples per year to obtain a precision uncertainty in the interval 0.5 - 0.4 - 0.3 - 0.2 - 0.1 ranges from 19 - 356. With seasonal adjustment, the required number of samples reduced to the range 3 - 62.

To assess the effect of number of samples per year on precision of annual mean estimates, we used algal biomass data from Lake Atnsjøen. Annual means were calculated using data for 1-5 monthly samples per year, and the coefficient of variation was compared for increasing number of samples.

Fish

Data from benthic gill-nets, 0-10 m and pelagic gill-nets, 0-6 m was analysed for trout whereas only data from benthic gill-nets, 0-10 m was used in the analyses of charr. We assume that the temporal variance due to changing environments act simultaneously on all individuals in the population, so the expected population change due to environmental fluctuations will be accumulated over all individuals and therefore increasing with population size. For a species with life span more than one year, we must necessarily expect dependence between observations. We modeled the population dynamics in two alternative ways:
1) If we consider the time dependence in the series we could model the population dynamics as a diffusion process with infinitesimal mean (expected change into the next year; often modeled as a classical deterministic growth equation):

$$m(x) = rx - xg(x)$$

where x is the population size, r is the specific growth rate at small densities and g(x) the density regulating term defined as an increasing function with g(0)=0, m(x=K)=0 when K is the carrying capacity. The infinitesimal variance (the stochastic term in the population dynamics) ca be written:

$$v(x) = \sigma_e^2 x^2$$

where is the environmental variance, affecting all individuals equally. We will here ignore the demographic variance, assuming that individual differences in fertility and mortality do not affect the total population dynamics significantly. A first order approximation to estimating is:

$$\hat{\sigma}_e^2 = \frac{2}{(t_{i+1} - t_i)}\left[1 - \frac{\overline{x}_i \overline{x}_{i+1}}{\overline{x}_i^2}\right] = \underline{0.075}$$

2) If we assume the population sizes at different years to be independent, i.e. they are fluctuating around some mean level (the carrying capacity) we find:

$$\hat{\sigma}_e^2 = \frac{Var(x)}{E(x)^2} = \frac{22.25}{17.8^2} = \underline{0.070}$$

Microcrustaceans

The temporal variation was not analysed explicitly but the sampling efficiency was studied by comparing species composition from accumulated species lists over years (from 1 to 7).

2.2 Results

2.2.1 Selection of most important lake types

Ideally the Norwegian monitoring network for reference sites (RN) should include lakes representing all the Norwegian lake types (Lyche Solheim and Schartau 2004). Since there are up to 24 lake types in each of six different ecoregions, the number of lakes in the RN would be very high, if all lake types should be represented. Moreover, there are certain lake types, where there are few, if any lakes in reference conditions today. Examples of such lake types are lowland lakes with moderate-high alkalinity, which are mostly eutrophied today, and highland lakes with low-alkalinity in the Southern Ecoregion, which are mostly acidified today. The actual RN thus cannot be expected to include all existing lake types. For lake types with too few existing reference sites, other methods than spatial monitoring data have to be used to set reference conditions. This is further outlined in the section on “remaining issues” below.

The lake types prioritized in the proposed RN are those selected for intercalibration (IC) in the Northern Geographical Intercalibration Group (N-GIG) (Lyche-Lyche Solheim and

Schartau 2004), as well as other special Norwegian lake types, which are likely to be vulnerable to pressures, such as eutrophication or acidification. The most important special Norwegian lake types are boreal or highland lakes with very low alkalinity (alk. < 0.05 meq/L or Ca < 1 mg /L), which are vulnerable to acidification. According to this 10 basic lake types are proposed to be included in the RN:

- Lowland
  - Low alkalinity, clear
  - Low alkalinity, humic
  - Moderate alkalinity, clear
  - Moderate alkalinity, humic
- Boreal
  - Very low alkalinity, clear
  - Low alkalinity, clear
  - Low alkalinity, humic
  - Moderate alkalinity, clear
  - Moderate alkalinity, humic
- Highland
  - Very low alkalinity, clear
  - Low alkalinity, clear

Some of these lake types are not common in all the 6 ecoregions, and the total number of types therefore can be reduced accordingly. Examples of rare types are very low alkalinity lakes in Northern Norway, and moderate alkalinity humic lakes in Southern and Western Norway. These types will therefore not be prioritized in the design of the reference network for lakes.

Although lake depth is not used in the Norwegian typology, the RN should include both shallow and deep lakes for each of the selected basic lake types, since their response to climate change is expected to differ (see web-site for the EU-project Eurolimpacs: www.eurolimpacs.ucl.ac.uk).

2.2.2 Occurrence of reference lakes in different regions and types

To restrict the number of lakes types as much as possible, we propose to give priority to those geological types which are assumed to be common in the different ecoregions and altitude regions. This results in a total of 51 prioritized lake types, which is a reduction from the theoretical maximum of 90 types (6 ecoregions x 3 altitude regions x 6 geological types) **Tabell 2**. This assumption should be checked after the addition of more reference lakes from the results of the characterisation projects in the next phase of the project.

The distribution of the 134 selected reference lakes among the different regions and selected basic types are shown in **Tabell 2**. As can be seen from the table, the large majority of the selected lakes (118 lakes) belong to one of the prioritized lake types.

Low (43 lakes) or very low (50 lakes) alkalinity clear water lakes in boreal areas in the Eastern, Western and Northern Coastal ecoregions were represented with the highest number of lakes. Humic lakes with low alkalinity were also represented in small numbers in the Eastern and Northern ecoregions (20 lakes). Moderate alkalinity lake types were represented with few reference lakes (16 lakes), and all except one are located in Northern Norway.

The selected lakes represent only 4% of the total number of lakes (> 0.5 km^2) indicated to be "clearly not at risk" according to the results from the characterisation work (NVE pers.

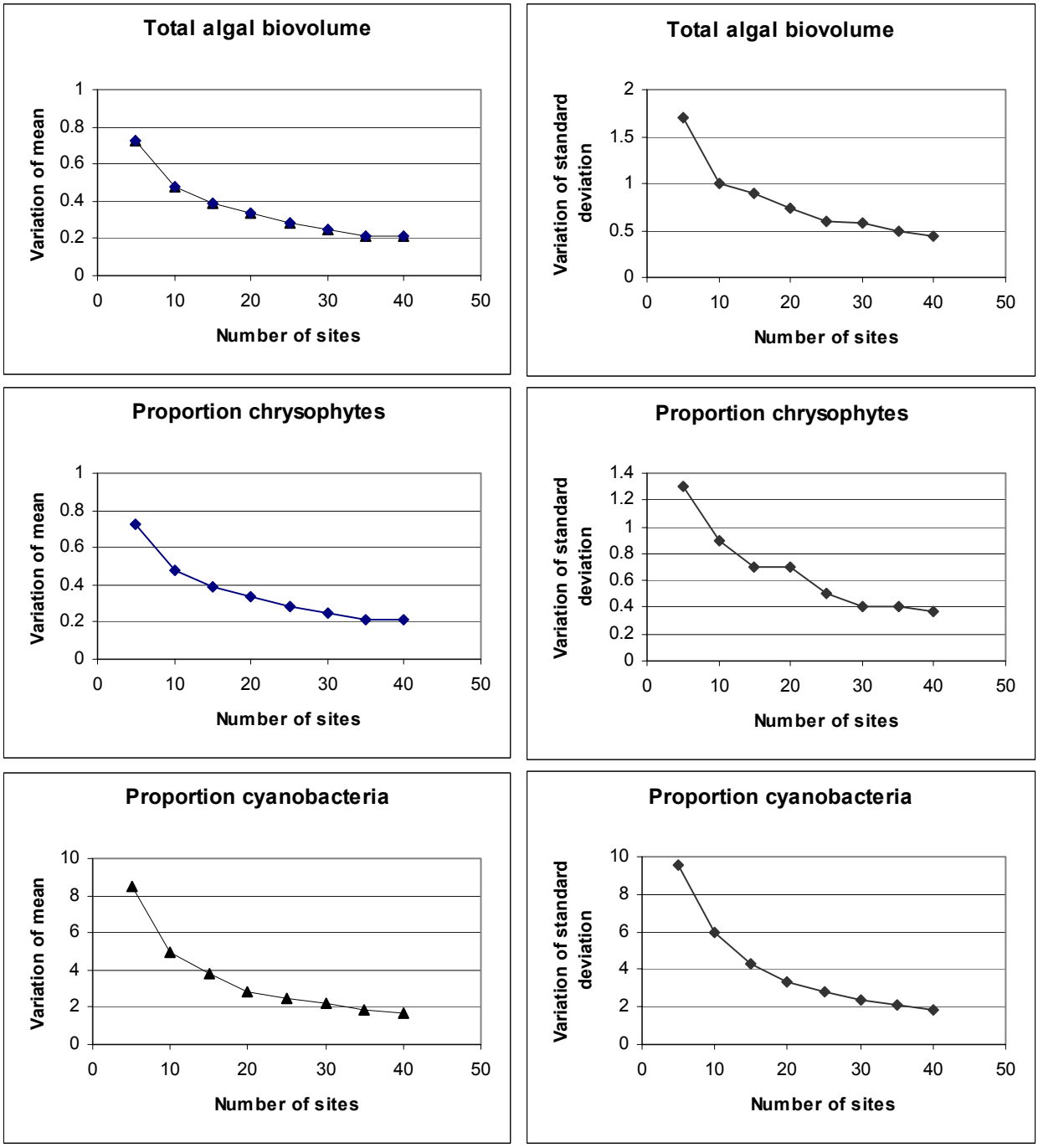
comm.) (see chapter 2.1.1 and remaining issues below). More reference lakes can be added from a list of these lakes after removal of acidified lakes.

Tabell 2. Distribution of selected reference lakes among different regions and types. Yellow fields show prioritized lake types.

		very low alk		low alk.		moderate alk.			
Ecoregion	**Altitude**	**clear**	**humic**	**clear**	**humic**	**clear**	**humic**	Total	Total prior
Eastern									
	Lowland	0	0	1	1	0	0	2	2
	Boreal	2	1	2	8	1	0	13	12
	Highland	6	0	2	0	0	0	7	7
Southern									
	Lowland	3	0	0	1	0	0	4	4
	Boreal	3	0	0	1	0	0	4	4
	Highland	2	0	2	0	0	0	6	6
Western									
	Lowland	8	0	15	0	0	0	23	23
	Boreal	16	0	4	1	0	0	21	21
	Highland	1	0	2	0	0	0	2	2
Central									
	Lowland	1	0	0	1	0	0	2	1
	Boreal	6	1	2	0	0	0	9	8
	Highland	2	0	0	0	0	0	2	2
Northern - coastal									
	Lowland	0	0	3	2	2	2	9	9
	Boreal	0	0	1	3	4	2	10	10
	Highland	0	0	4	0	0	0	4	4
Northern - inland									
	Lowland	0	0	0	0	0	0	0	0
	Boreal	0	0	3	2	2	2	9	9
	Highland	0	0	2	3	0	1	6	5
Sum		50	2	43	23	9	7	134	
Sum prior.		49		43	23	8	6		129

2.2.3 Statistical testing /recommendations of no. of sites per type

To determine the required number of reference sites, we have analysed how the number of sites affects the precision for estimates of the mean and standard deviation for chemical elements (pH, ANC and Tot P) and biological elements (algal biovolume and algal community composition) Figur 3. In general the figure show a sharp decline in variation (i.e. an increase in precision) from 5 to 10 sites, and and a less steep decline from 10 to 20 sites. The decrease in variation from 20 to 30 sites and from 30 to 40 sites is of similar magnitude as from 20 to 10 sites. Analyses of the chemical elements show similar patterns. We recommend 20 sites per lake type as the optimal number of sites and 10 sites as a minimum.



Figur 3. Statistical analyses of biological elements from low-alkalinity clear water lakes. For each number of sites (*n*), *n* sites is randomly sampled 250 times and the mean and standard deviation is calculated for each set of *n* sites. The figure shows how the precision for estimated mean and standard deviation increases with the number of reference sites. The y-axis represents the variation in mean and standard deviation among these 250 sets, calculated as the difference between the upper and lower 2.5% quantile.

Assessment of spatial variance in trout populations show that lakes in eco-region Northern Norway, coastal parts has a significant smaller mean CPUE (17.9 per 100 m2) than lakes in all other regions (31.5 – 40.2 per 100 m2). No data exist from Northern Norway, inland parts. Mean CPEU in Eastern Norway (40.2 per 100 m2) is significantly higher than in Western Norway (31.5 per 100 m2) and Southern Norway has a much larger standard deviation (33.4)

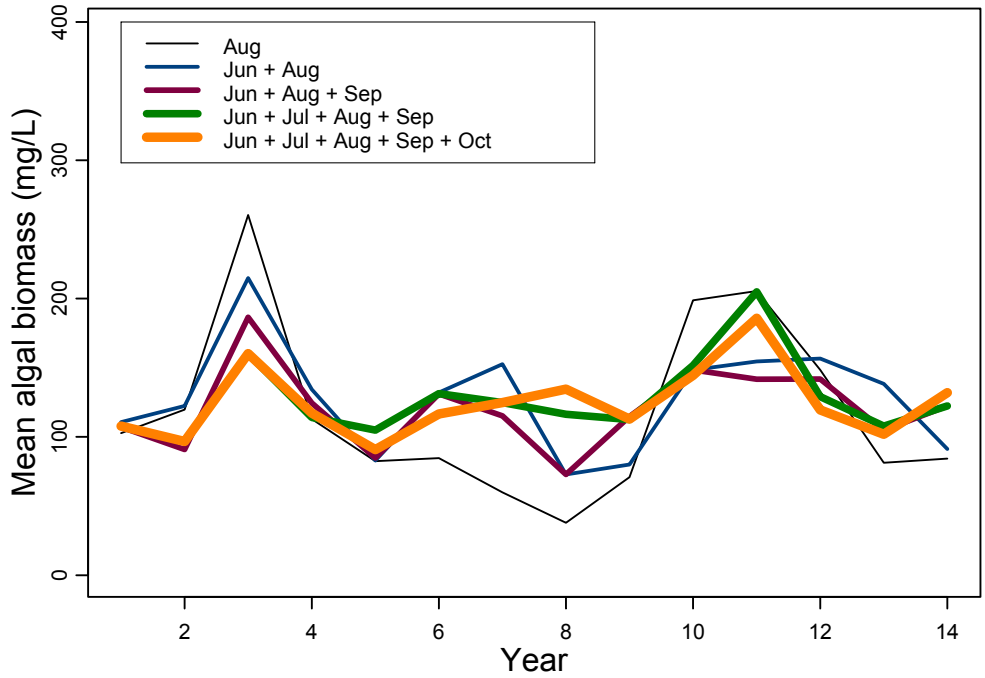
than the others (9.2 – 22.6). The results from Southern Norway should however be used with caution since the lakes in this region has uncertain ecological status although the water quality may be good (liming, acidification). There were no significant differences between boreal and highland lakes in mean CPUE (pooled mean: 32.6, variance: 21.5).

Our analysis of spatial variation in species composition of microcrustaceans is very rough; the sampling effort is probably not constant and slightly impacted lakes may be included in the dataset. Furthermore, only one lake type has been assessed so far. A preliminary analysis of the data from boreal, low alkalinity, clear lakes in Central Norway indicate that the variance (CV in %) decrease clearly with increasing number of lakes up to approximately 10 lakes. Somewhere between 15 and 25 lakes the decrease in variance is leveling out.

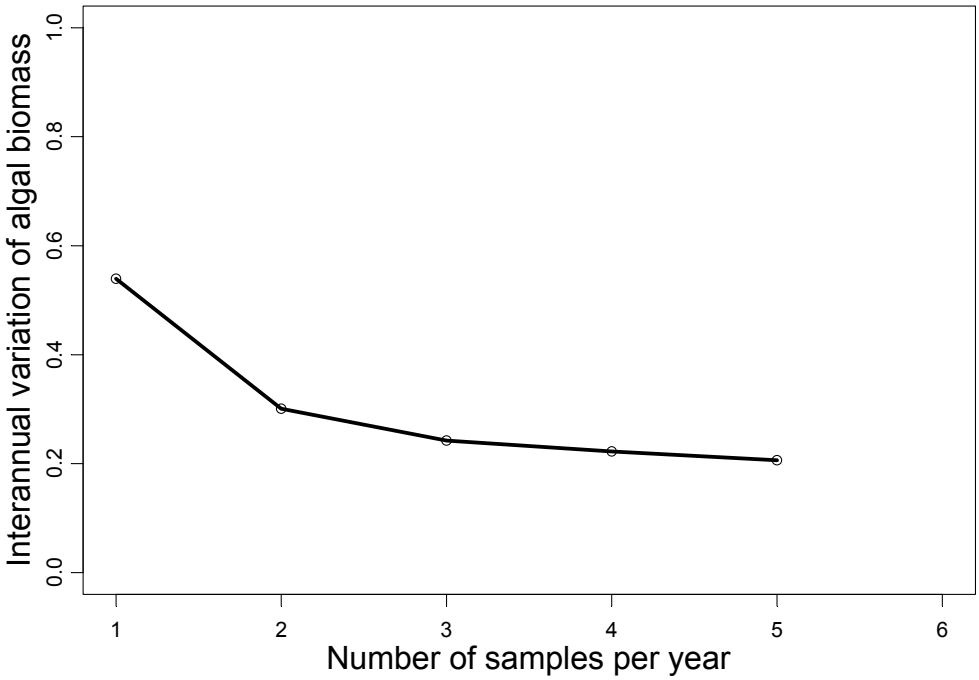
2.2.4 Statistical testing /recommendations of sampling frequency

Phytoplankton

The importance of sampling frequency (number of samples per year) for the precision of estimates is illustrated in figures **Figur 4** and **Figur 5**. **Figur 5** shows how the interannual variation, measured as the coefficient of variation (standard deviation scaled by mean), is reduced as the number of samples per year increases. In this case estimated variation appears to stabilize with 3-4 samples per year. However, these data are from an ultraoligotrof lake. More eutrophic lakes usually have higher seasonal variation. For these lakes, the number of samples per year will therefore have a larger importance for the precision of the estimated annual mean. A more precise estimate of the interannual variation within a site also increases the probability for detecting a temporal trend.



Figur 4. Interannual variation of mean seasonal phytoplankton biomass per year for Lake Atnsjøen 1988-2002, as a function of sampling frequency from 1 to 5 monthly samples per year.



Figur 5. Interannual variation, measured as the coefficient of variation (standard deviation scaled by mean), as a function of the number of samples per year or season.

Fish

The two approaches for estimation of temporal variance in the trout population of Lake Atnsjøen gave relatively similar results whereas the estimates for the char population were rather different. The results indicate that the independence assumption is further from the truth for the char than for the trout population.

Microcrustaceans

The mean number of microcrustcean taxa missing from any one year was about 20-40% of the total recorded number of taxa during the 5-7 years of investigation. The results indicated that the accumulated species number may continue to increase whereas the accumulated number of indicator species showed only very minor changes after three years with investigations. The most dominant or abundant species were found nearly every year. As long as the assessment of ecological status focus on common species as well as the presence of sensitive versus tolerant species it seems that only a few years of observations are sufficient to provide a reliable general characteristic of the microcrustacean community at a given site.

2.2.5 Selection of elements and recommendations of sampling frequency

The elements to be included in RN monitoring are given in Annex V in the WFD, and further specified in the Guidance on Monitoring (ref.). Although zooplankton is not included in the WFD, we recommend zooplankton to be monitored in the RN, since zooplankton is a good indicator of ecological status, and has been used in monitoring of Norwegian lakes for many years. The list of elements selected for the RN are shown in Tabell 3.

Tabell 3. Selection of elements and recommended sampling frequencies for RN monitoring of lakes. Coloured cells indicate minimal requirements.

Biological quality elements	**Optimal sampling frequency**	**Minimal sampling frequency**
Phytoplankton	**Annually**	**Every 3 years**
Taxonomic composition	Biweekly in growth season	Monthly in growth season
Biomass (chlorophyll and biovloume)	(10/year, April-Oct)	(5-6/year, May-Oct)
Diversity (evenness)		
Macrophytes	**Every 3 years**	**Every 6 years**
Taxonomic composition	1/year (September)	1/year (September)
% cover		
Lower growth limit		
Diversity		
Zooplankton	**Annually**	**Every 3 years**
Taxonomic composition	Monthly in growth season	Monthly in growth season
Abundance (population density or biomass)	(5-6 /year)	(5-6/year)
Diversity		
Benthic fauna (littoral)	**Every 3 years**	**Every 6 years**
Taxonomic composition	2/year (May + October)	1/year (October)
Abundance		
Diversity		
Fish	**Every 3 years**	**Every 6 years**
Taxonomic composition	1/year (September)	1/year (September)
Abundance (poulation density)		
Age structure		
Physico-chemical quality elements	**Annually**	**Every 3 years**
Tot-P (+ PO4 in bottom waters)	10/year (April-Oct)	5-6/year (May-Oct)
Tot-N and NO3	10/year (April-Oct)	5-6/year (May-Oct)
Secchi depth	10/year (April-Oct)	5-6/year (May-Oct)
Colour	10/year (April-Oct)	5-6/year (May-Oct)
Turbidity	10/year (April-Oct)	5-6/year (May-Oct)
Temperature	10/year (April-Oct)	5-6/year (May-Oct)
Oxygen (bottom waters	2/year (march and nov)	2/year (march and nov)
TOC	10/year (April-Oct)	5-6/year (May-Oct)
pH	10/year (April-Oct)	5-6/year (May-Oct)
Ca	10/year (April-Oct)	5-6/year (May-Oct)
ANC	10/year (April-Oct)	5-6/year (May-Oct)
Hydromorphological quality elements	**Annually**	**Annually**
Water level fluctuations	Weekly (automatic)	Weekly (automatic)
	(daily during high flow)	(daily during high flow)
Time and duration of ice cover	Remote sensing?	Remote sensing?

The proposed frequencies are compatible with the duration of a WFD river basin management plan, which have to be revised every six years.

2.2.6 Selected reference lakes

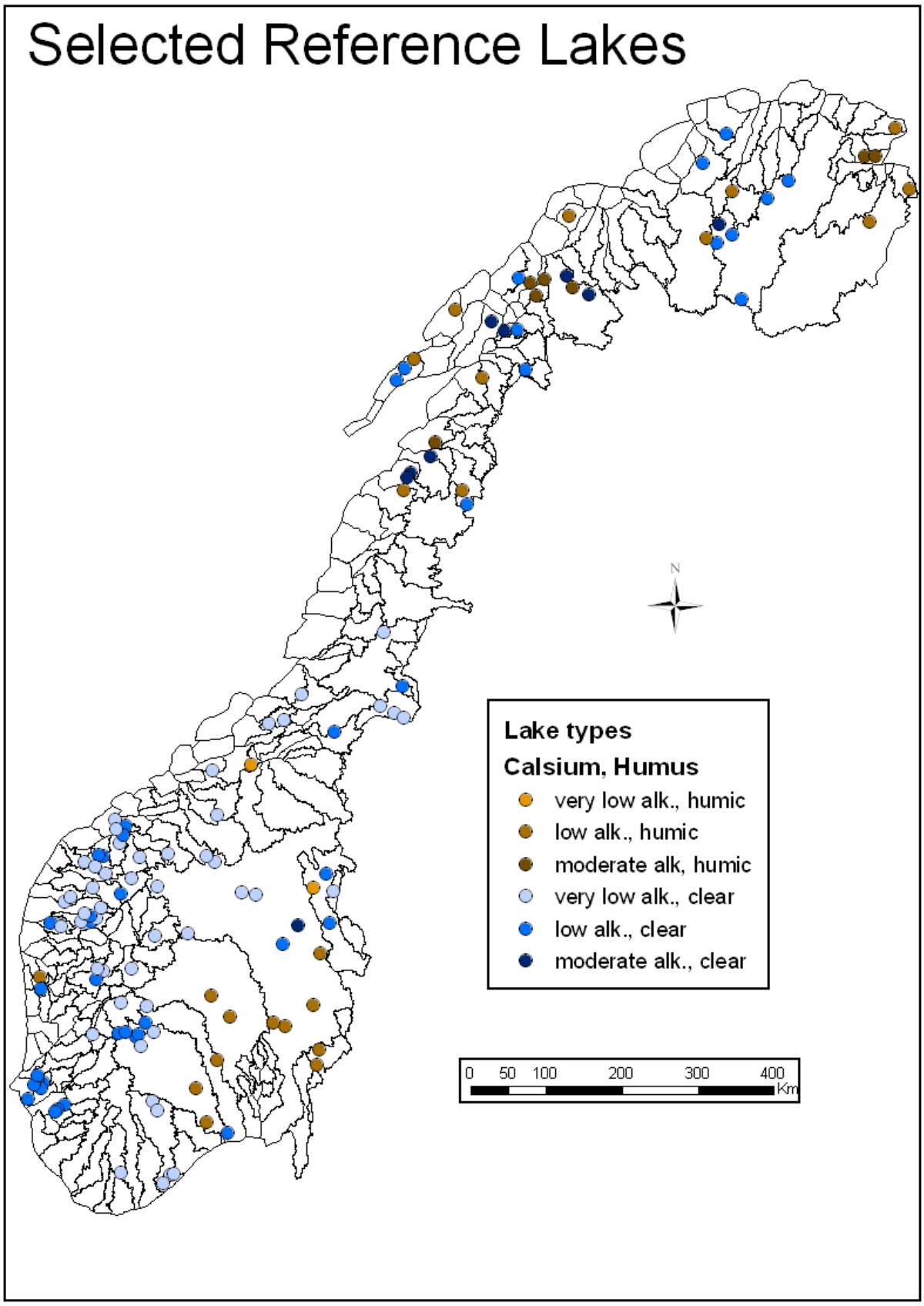
The selected reference lakes are shown in 6.Vedlegg A. and in **Figur 6**. The number of lakes in most of the regions and types are not sufficient to provide acceptable statistical power in the monitoring network (see below). Additional lakes thus have to be added from the complete list of lakes identified to be “not at risk” in the characterisation projects.

The sufficient number of reference lakes to be included in the reference monitoring network should be the total number of types multiplied with the number of lakes per type required to obtain acceptable statistical power in the monitoring network. The total number of types required for different elements are shown in **Tabell 4**. The table is based on the ecoregions and the 10 basic types identified above (see 2.2.2).

Not all elements differentiate between all the ecoregions and all the basic types, and the number of types can therefore be reduced accordingly. Phytoplankton have not been shown to differentiate between ecoregions, altitude regions nor between very low and low alkalinity lakes. Thus this element only show significant differences between the four basic types which are combinations of low and moderate alkalinity and low and high humic content. Macrophytes do not differ between the two Northern ecoregions, between lowland and boreal, nor between very low and low alkalinity (Marit Mjelde pers. comm.). Zooplankton and benthic fauna do not differ between the Eastern and Southern ecoregions, whereas fish are different in all the ecoregions and altitude regions. Fish is also assumed to distinguish between very low and low alkalinity and humic content, but not between low and moderate alkalinity, although this has not been shown statistically for Norwegian data at the moment.

The maximum number of lakes to be selected for the optimal design is thus 840, whereas the minimal design is 420. If initial monitoring shows that there is actually no or very little difference between some of these types for some of the elements, then the number of lake types and sites monitored may be decreased.

On the other hand, if the lake types have to be subdivided into different depth and/or size categories, the number of sites should be increased accordingly.



Figur 6. Selected reference lakes. Lines show borders of main watersheds

Tabell 4. Total number of types to be included in the RN for different biological elements. For optimal design 20 lakes per type are used (see statistical analysis above), and for minimal design 10 lakes per type are used.

Biological element	Ecoregions	Altitude+ chemistry (basic types)	total # lake types	optimal # lakes	minimal # lakes	comment
Phytoplankton	1	4	4	80	40	no difference between ecoregions, no difference between altitude regions, only 4 basic types
Zooplankton	5	7	42	840	420	difference between ecoregions, difference between highland and lower altitude regions,
Macrophytes	5	7	23	460	230	difference between ecoregions, difference between highland and lower altitude regions,
Benthic fauna* (only littoral)	5	10	42	840	420	difference between ecoregions and between all the three altitude regions
Fish	6	10	39	780	390	difference between ecoregions and between all the three altitude regions

*Profundal fauna should be evaluated in next phase

2.2.7 Cost estimate for optimal and minimal design

A first attempt has been made to estimate necessary costs for the monitoring of reference lakes according to the different types, numbers of sites per type, and sampling frequency necessary for the different elements. The optimal design applies 20 sites per type, include zooplankton and applies a higher sampling frequency, whereas the minimal design applies 10 sites per type, excludes zooplankton and applies a lower sampling frequency (see **Tabell 5**).

The optimal design is estimated to > 80 mill. NOK per year, and almost 200 mill. NOK for the first 6 year RBMP (River Basin Management Plan) period, in which the zooplankton component alone is 30 mill. per year or 60 mill. NOK for the whole period. This optimal design is recommended for the first three year period, in order to obtain sufficient data to establish precise reference values and confidence levels for all the elements. If cost reductions are necessary the zooplankton component should not have first priority.

If this initial monitoring suggest that there are no or very small differences between the types for certain elements (i.e. fish), the number of types and sites can be reduced, and so will the costs.

The annual costs can also be reduced if the monitoring programme is organised in a way in which only one third of all the sites are monitored each year.

The minimal design is estimated to roughly 20 mill. NOK. In this design only the phytoplankton and water chemistry are proposed to be monitored twice during the six year period of the RBMP (river basin management plan). This may not be sufficient to reveal trends due to climate change. Further statistical analyses should be used in the next stage of the project to estimate the minimum number of monitoring years necessary to reveal trends due to climate change.

Tabell 5. Cost estimate for monitoring of reference lakes

Activity	Initial costs	Cost per sample	Optimal design: Cost per site	Optimal design: Total annual costs*	Optimal design: Total costs per 6 year period*	Minimal design: Cost per site	Minimal design: Total annual costs*	Minimal design: Total costs per 6 year period*
First survey of hydro-morphology (4 hours per site?)	3							
Purchase and installation of field equipment for automatic recording of water level fluctuations (need input from NVE)	?							
Sampling, analyses								
Physico-chemical elements, incl. observations of water level fluctuations		4	40	3200	19200	24	960	1920
Phytoplankton		4	40	3200	19200	24	960	1920
Zooplankton		6	36	30240	60480			
Macrophytes		16	16	7360	14720	16	3680	3680
Benthic fauna (littoral)		16	32	26880	53760	16	6720	6720
Fish		16	16	12480	24960	16	6240	6240
Reporting				800	1600		600	600
Coordination and administration	?			200	1200		150	300
Total costs excl. VAT		62	180	84360	195120	96	19310	21380

* Total costs indicate the total costs for monitoring of all the sites.

2.2.8 Remaining issues

- **Uncertainty**: The present results and recommendations for a design for a monitoring programme for reference sites are largely based on expert judgement. The statistical power and uncertainty cannot be quantified until more data have been compiled and more statistical analyses have been done. This has not been possible within the time and resource constraints in the present project. The proposed design should therefore only be used as preliminary rough recommendations demanding further testing before a future monitoring programme can be designed with an acceptable level of confidence.

- **Addition of more sites:** The number of lakes in most of the regions and types are not sufficient to provide acceptable statistical power in the monitoring network. Additional lakes thus have to be added from the complete list of lakes identified to be "not at risk" in the characterisation projects. As soon as this list is made available, this can be done.

- **Depth categories:** For all basic types included both shallow and deep lakes should be included in sufficient numbers to obtain sufficient statistical power for both depth categories. Thus data on mean depth is necessary before the final selection of lakes are made.

- **Further need and possibilities for statistical testing**

- The database on microcrustaceans (Cladocera, Copepoda) from Norwegian lakes include data (species composition, presence/absence) from approximately 2 800 sites. All sites have been typified and the database has been sorted according to type. Some preliminary analyses on spatial variance have been performed. After excluding impacted sites (with help of the results from the Characterization projects) and correcting the data for varying sampling effort this dataset may be used for assessing spatial variance (within and between lake types) in species composition.

- Time-series on fish populations from Lake Atnsjøen (20 years, trout and charr), Lake Femunden (23 years, whitefish) and Lake Høysjøen (19 years, trout and charr), representing two different laketypes and two ecoregions, may be used for quantification of year-to-year variance in fish abundances and age-structure. Data cleaning/correction for varying sampling effort are necessary for the datasets from Femunden and Høysjøen before further analyses.

- If climatic change causes a temporal trend in the abundance of a chemical or biological element in reference lakes, this trend can be estimated by linear regression as a slope different from zero. The probability (power) for detecting a trend will increase with the number of years of observation, as well as the sampling frequency and the magnitude of the trend. The power will decrease with the natural variation within and between years, and with sampling variation. Power can be calculated for different combinations of number of samples per month and number of years of observation, to show which sampling design gives the highest probability for detecting a certain linear trend.

- **Models and paleoecology:** For lake types with few existing sites other mean of estimating their reference conditions should be attempted. For lakes with very low alkalinity in the Southern ecoregion, where the large majority of lakes are acidified, new models may be used (ref. Hindar). For lakes with moderate alkalinity in the lowland areas of most ecoregions, where the large majority of lakes are eutrophied, paleoecological methods should be used to estimate the reference conditions. We propose that at least xx lakes from Eastern, Western and Central Norway should be selected for this purpose. Selection of these lakes should be done in the next stage of the project.

- **NGIG collaboration:** The number of lakes selected for reference conditions monitoring in Norway can be reduced through collaboration in the NGIG for at least some of the IC-types. This will have to be discussed further at the coming workshops in the NGIG in April and September.

- **Linking RN to other monitoring:** The selected reference lakes should be checked versus existing lake monitoring in Norway, to ensure consistency between different monitoring programmes. Of special importance in this regard is the coordinated monitoring of long-range transboundary pollutants (acidification, heavy metals and POPs), as well as the hydrological monitoring of water level fluctuations performed by NVE. This can easily be done by comparing the site lists for the different programmes with the revised site list of reference lakes after addition of more sites, as suggested above.

3. Rivers

3.1 Methods

3.1.1 Datasets on potential reference sites

The basis for the selection of reference river-sites is Table B2 in Lyche Solheim et al. (2003), which presented 50 rivers selected from the potential sites for monitoring of biological diversity in Brandrud et al. (2000), and supplemented with rivers from various biological studies. The reference status of the rivers has been checked by applying the results from the Characterization Projects performed in 2004 (status per January 2005). In this process all limed/acidified rivers in Southern Norway as well as other rivers or river-sites indicated as at risk and potentially at risk were excluded.

Additional reference-sites were selected from the total list of river-sites indicated as not at risk from the Characterization Projects (not yet completed).

3.1.2 Chemical and biological datasets used for statistical testing/recommendations

Generally, there are very few, if any, datasets from running waters which are suited for estimation of natural spatial variation. The database on macroinvertebrates from Norwegian rivers, which is managed by NINA, includes approximately 1400 sites, representing more than 300 rivers, covering the whole country. Both impacted as well as non-impacted rivers are included in this database. The data are based on various sampling methods and -effort, and can therefore not be used for estimation of natural variation without extensive quality assurance and data-cleaning. However, the data may be made available for this purpose by late spring 2005 through the further development of the database VannInfo.

Consequently, the present recommendations on number of sites per river type are based on information on spatial variation from the literature (STAR?) as well as general statistical considerations.

To order to assess the year-to-year variation in biological quality elements, data on benthic algae (1986-1997), macroinvertebrates (1987-2002), and fish (1985-1991) from the FORSKREF watercourse Atna was used.

3.1.3 Brief description of methods used for statistical testing

Benthic algae from Atna River (summary from Lindstrøm et al. 2004):
Sampling efficiency was studied by comparing species composition from individual years with accumulated species lists over years (from 1 to 11).

Spatial variation in species composition was analysed by an ordination technique; the correspondence analysis method. The resulting site scores serve as a diversity index based on the species composition of the sites, and differences in site scores indicate differences in species composition between the sites. Correlation between site scores and environmental factors measured at each station was analysed by linear regression.

Temporal (inter-annual) variation in species composition was validated by calculating a similarity index (S; Sørensen's similarity index) based on qualitative data. The index varies between 0 and 1. According to experience with this index in a large number of Norwegian rivers, two samples should be regarded as similar when the index is 0.6 or higher. Correlation between diversity and environmental variables was analysed by linear regression.

Macroinvertebrates from Atna River (summary from Aagaard et al. 2004):
Sampling efficiency was studied by comparing species composition (Ephemeroptera, Trichoptera) from individual time series and individual years with accumulated species lists over a number of time series (from 1 to 5 per year) and over years (from 1 to 14).

Spatial variation in macroinvertebrate composition and diversity was not analysed explicitly, but a comparison of the species list (Ephemeroptera, Plecoptera, Trichoptera, Limonidae, Chironomidae) and composition of functional groups from each of the sampling sites was performed.

Fish from Atna River (summary from Hesthagen et al. 2004):
Spatial differences in size/growth and densities of Siberian sculpin (*Cottus poecilopus*) and young brown trout (*Salmo trutta*) were tested by variance analysis (t-test, U-test).

3.2 Results

3.2.1 Selection of most important river types

In general, all common Norwegian river types should be included in a network of reference sites for monitoring of ecological status. However, this may be difficult due to financial or practical reasons. If prioritization among river types is required, the highest priority should be given to the following types:

- Intercalibration types (Northern GIG river types)
- Types especially sensitive to pressures identified as relevant for Norway (all Lowland river types due to eutrophication; Boreal and Highland, low alkalinity rivers due to acidification).
- Other river types which are common in Norway but not necessarily in the rest of Europe.

The river types suggested to be of high priority are presented in colours/bold types in **Tabell 6.**

3.2.2 Occurrence of reference sites in different regions and types

Among the 50 potential reference rivers presented in Table B2 in Lyche Solheim et al (2003), 31 rivers include river-sites identified as not at risk. Additional rivers have been selected giving a total number of 42 rivers including yy river types and zz river sites (**Tabell 6** and **6.Vedlegg B.**). For most of the rivers more than one river-type and more than one water-body per type was identified. The total number of reference sites, based on the output from the Characterization Projects, is expected to be much higher. However, the complete and updated dataset from the Characterization Projects have not been available for our project.

The highest number of sites was found for the small and medium sized, low alkalinity, clear rivers in all climate regions, covering Central Norway and the inland parts of Northern Norway. No reference sites were found in Southern and South-Western Norway, due to acidification, and the number of reference sites was also low in the coastal part of Northern

Norway (probably possible to increase the number for the last region). Potential reference sites of Lowland river types were only found in Central Norway and in the inland parts of Northern Norway. However, for the latter ecoregion Lyche Solheim & Schartau (2004) recommend not to indicate Lowland as a separate climate region.

The following river types were represented with few sites:

- low alkalinity, humic rivers in Lowland and Highland
- moderate alkalinity, humic rivers (=mixed) in all climate regions and eco-regions except for the inland parts of Northern Norway

Rivers which should be included in the reference network for monitoring of ecological status in Norway are presented in 6.Vedlegg B. Recommendation of specific sites in each river is not possible without further investigations. Therefore, for several of the rivers alternative river-segments (water-bodies) are suggested. Among these one or several reference site(s) may be selected.

Tabell 6. Number of potential reference-sites per river-type based on the selection of reference rivers in Lyche Solheim et al. (2003) checked against the results from the Characterization Projects. The sites belong to the size category small-medium rivers (10-1000 km^2), If not otherwise indicated. Vs: very small rivers (<10 km^2), L: large rivers (>1000 km^2). Yellow: IC-types (Eastern, Western, Central ecoregions), Blue: other river-types sensitive to acidification, Pink: other river-types sensitive to eutrophication, Green: other common Norwegian river-types.

Egoreg	Altitude	Very low alk		Low alk		Moderate alk	
		clear	organic	clear	organic	clear	organic
Eastern	Lowland						
	Boreal	1		4	6		
	Highland	1		4	(5[1])		
Western	Lowland						
	Boreal	2 (Vs:1)					
	Highland	4					
Central	Lowland			3 (L:1)			
	Boreal			10 (L:3)			
	Highland			2			
Northern - coast	Lowland						
	Boreal			2			
	Highland			1		2	
Northern - inland	Lowland			2	1	1(L:1)	1
	Boreal			1	5	2	8 (L:1)
	Highland			4	1	1	2

[1] Glacial rivers (not organic)

3.2.3 Statistical testing / recommendations of no. of sites pr type

From the studies in Atna River we know that spatial variation may be high, even within one water-body type. Both benthic algae (Lindstrøm et al. 2004) and macroinvertebrates (Aagaard et al. 2004) displayed pronounced zonation in species composition and diversity along the watercourse. Also growth and abundance of the fish species Siberian sculpin (*Cottus poecilopus*) and brown trout (*Salmo trutta*) showed large spatial variation (Hesthagen et al. 2004). Minor physical differences, such as differences in micro-/mesohabitat and climate, may affect biological parameters. To some degree, this may be taken care of when designing the monitoring program. Zonation in species composition and diversity is probably

particularly pronounced in water courses with natural lakes (Aagaard et al. 2004) and for boreal rivers/river-sections in Eastern Norway (probably also true for Central Norway). Lakes are present in most Norwegian water courses. The export of particulate organic matter (plankton, etc.) from the lake induces a completely different macroinvertebrate community at downstream localities compared to upstream sites. The boreal rivers in Eastern Norway are long, and cover a large geographical area compared to corresponding river types in Western and Northern Norway.

Despite some general knowledge on temporal and spatial variability in biological data, quantitative information on natural variance and the contribution from each of the variance components is very sparse. With good variance estimates monitoring environmental changes or pollution effects could be done with much lower effort through methods based on modelling. However, to come up with good variance estimates, we need many more observations than when estimating averages, especially if the distribution is skewed. Before establishing a final network of reference sites, biological data from a high number of sites should be sampled in a standardized manner (effort, method etc. are kept constant) to be able to establish levels of natural variation. The selection of preliminary reference sites should cover as many water-types and eco-regions as possible.

3.2.4 Statistical testing / recommendations of frequency of observations per site and element

Timing and number of observations per year:
Recommendations of frequency of observations per site and element are based on recommendations given in Brandrud et al. (2000) and information on seasonal variation for benthic algae and macroinvertebrates in Lindstrøm et al. (2004) and Aagaard et al. (2004).

Generally, biological data show high seasonal variability and this is especially true for abundance data. Different species may occur in peak numbers at different times of the year, so the community composition will vary during the season. Good abundance estimates require quantitative sampling methods and high sampling effort with frequent sampling through the season. The quantitative sampling methods developed for sampling of flora and fauna in rivers are only suitable for sampling of certain groups of organisms. Assessment of human impacts is therefore based on qualitative or semi-quantitative data. With focus on common species as well as tolerant versus sensitive species it seems that relatively few sampling series per year are sufficient to provide a reliable characteristic of the flora and fauna at a given site. It is, however, important to standardize time of collection, especially for short-lived organisms.

Aagaard et al. (2004) show that one sampling series per year always resulted in a high number of missing macroinvertebrate taxa (Ephemeroptera, Plecoptera) and that the number of missing taxa decreased with increasing number of sampling series per year. In order to include all invertebrate species, a very intensive and expensive monitoring program is necessary (see also below). However, the difference between two and three sampling series per year was minor and two sampling periods per year are probably sufficient to ensure the inclusion of most of the abundant species as well as the indicator species of interest in environmental impacts studies. The time of sampling may, however, vary depending on the type of impacts. In general sampling of macroinvertebrates should be done in mid summer and late autumn because most species have late instar larvae that are easy to identify, during one of these periods. Monitoring of impacts of liming or acidification requires data from spring (shortly after ice break-up) because absence of sensitive taxa in this period may indicate acidic episodes in rivers which at other times of the season have good water-quality.

The diversity of benthic algae in Atna River increased from spring to autumn (Lindstrøm et al. 2004). The inter-annual variability in diversity was less pronounced in autumn than in spring. This support the general impression that the environmental conditions were more stable and the algal flora better developed in autumn. Some species are only observed in spring and early summer and therefore two sampling series per year are recommended. However, sampling in autumn should be given highest priority.

Number of years with observations:
Differences between years in species composition and diversity of benthic algae in Atna River were surprisingly small (Lindstrøm et al 2004), and it may seem that only a few years of observations are sufficient to provide a reliable general characteristic of the benthic algae community at a given site. Accumulated number of taxa observed in autumn samples remained more or less unaltered after an initial observation period of three to four years.

Aagaard et al. (2004) show that the mean number of Ephemeroptera and Plecoptera taxa missing from any one year were about 50% of the total recorded number of taxa during the 15 years of investigation. Combining data from two, three and four years, resulted in a substantial decrease in the number of missing taxa. The most dominant or abundant species were found nearly every year while 30-60% of the species were found in only 25% of the years.

Rare species are often of great interest from a biodiversity conservation aspect, but monitoring of a large number of rare species will always be an expensive and difficult task (see Aagaard et al. 2004). Monitoring environmental changes or pollution effects, on the other hand, could be done with much lower effort through methods based on models of community structure or diversity indices (Diserud & Aagaard 2002).

3.2.5 Selection of elements and sampling frequency

The following biological quality elements should be included in monitoring of reference conditions in Norwegian rivers:

- Benthic algae (eutrophication, acidification, hydromorphological pressure)
- Mosses (eutrophication, acidification, hydromorphological pressure)
- Macroinvertebrates (organic pollution, acidification, hydromorphological pressure, heavy metals)
- Fish (acidification, hydromorphological pressure)

Of the quality elements mentioned in Annex V, section 1.2.1 in the Water Framework Directive, only phytoplankton is considered as not ecologically relevant, and should not be prioritized in the monitoring of reference conditions. This recommendation is based on a general lack of suitable habitat for phytoplankton (slow-running deep waters) in Norwegian rivers. The same argument could also be used for river macrophytes, except for mosses which are more common in swift running, shallow rivers.

All the prioritized biological quality elements are included in the national monitoring program on liming and macroinvertebrates and fish are included in the national monitoring program on acidification. Assessment of local pollution (organic pollution and industrial effluents) is mainly based on monitoring of macroinvertebrates whereas impacts of hydromorphological pressures have been studied by monitoring of benthic algae, macroinvertebrates and fish.

Chemical, physio-chemical, and hydromorphological quality elements according to Annex V, section 1.1.1 in the Water Framework Directive should be included for all river-sites in the reference framework for monitoring of ecological status.

All sites should be sampled for three subsequent years following the sampling frequency recommended in **Tabell 7**

Tabell 7. Monitoring of reference conditions, Rivers: Recommendations on frequency of observations per site and quality element as well as time of sampling.

Element	Parameter	# samples per year	Time of sampling
Benthic algae	Species composition Indicator species Abundance	1	August/September[1]
Macrophytes (mosses)	Species composition Indicator species Abundance	1	August/September
Macroinvertebrates	Species composition Abundance (rel. or abs.) Indicator species	2 (abs. abundance: 3)	April/May[2], July/August, October/November[2]
Fish	Species composition Abundance Population parameters (age-structure, growth)	1	August/September
Chemical	Ca, Colour (TOC), Tot-P, Tot-N, NO3, pH, ANC, Turbidity Heavy metals	12 + weekly during floods 4 (once in each monitoring period)	All seasons All seasons
Physical	Temperature Time and duration of ice cover	Continuous (eventually event-based: local observer)	
Hydrological	Water flow	Continuous (neighbouring watercourses?)	All seasons
Morphological	River depth and width variation Structure and substrate of river bed Structure of riparian zone	4 (once in each monitoring period) 1 (once in each monitoring period)	All seasons August/September

[1] *most important period in assessment of benthic algae*
[2] *most important periods in assessment of acidification effects*

3.2.6 Selection of reference sites (optimal design and minimal design)

Rivers with existing data are presented in **Tabell 8** together with information on type of investigation (monitoring with time-series or other types) and which quality element that is/has been included.

Tabell 8. Existing studies and biological data from suggested reference rivers. Monitoring programs and other studies performed by DN: Directorate for nature management, MD: Norwegian Ministry of Environment, LMD: Norwegian ministry of Agriculture and Food, NVE: The Norwegian Water Resources and Energy Directorate, SFT: Norwegian Pollution Control Authority, Fm: County Governor's dep. of environment, HP-comp: Hydropower company. DN9: monitoring of liming effects. DN25: monitoring of acidification effects. SFT32: assessment studies of the Glomma watercourse. M: Macrophytes. B: Benthic algae. Z: Macroinvertebrates (zoobenthos). F: Fish. Biology, periodic studies: •• several quality elements. • 1-2 quality elements (primarily Macroinvertebrates and Fish). Mark: Biological studies may be related to other parts of the rivers than those river-sections suggested in 6.Vedlegg B. (table not completed).

Watercourse	Monitor.-program	Other studies	Biology frequent	Biology periodic	Water flow (NVE)
Haldenvassdraget	Fm/LND	SFT		•	
Glomma/Osa		NVE/HP-comp		••	
Glomma/Atnavassdraget			B, Z, F		
Glomma/Sjoa		?		?	
Glomma/Håelva (Røros)		?		?	
Begna	Fm/LMD	SFT		•	
Sandvikselva	Fm/LMD			••	
Gudbranddalslågen/ Otta/Bøvra (upper parts)		SFT/Fm		••	
Trysilvassdr/Røa/Mugga		?		?	
Skiensvass. (SW & upper parts)		SFT/Fm/NVE		••	
Osvassdraget	Fm/LMD			•	
Tyssevassdraget		Fm		•	
Etne					
Eidfjordvassdr/Veig		?		?	
Vosso	DN9&25	SFT/Fm	Z, F		
Ekso	DN9	NVE/HP- comp	M, B, Z, F		
Yndesdalsvassdr.	DN9		Z, F		
Aurlandsvassdr.		NVE/HP-comp		••	
Lærdalselva/Kuvella		DN		••	
Nausta	DN25		B, Z, F		
Gaularvassdr.	DN25		Z, F		
Ervikelven (Stadt)		?		F	
Oldenvassdr.		?		?	
Rauma		Fm		•	
Surna		Fm		•	
Driva		Fm?		•	
Stjørdalselva				•	
Namsenvassdr.		NVE/MD/Fm		•	
Vefsna				••	
Beiarelva		HP-comp		••	
Skjoma		NVE/HP-comp		••	
Saltdalsvassdr.		?		?	
Målselvvassdr.		?		?	
Reisaelva				•	
Altavassdr.		HP-comp		B, Z, F	
Lakselvvassdr.				•	

Børselvvassdr.		NVE/Fm		••	
Tana		SFT/Fm		••	
Pasvikelva		MD/DN		••	
Vesterelvvassdr./Sylt efjord				•	
Sendfjordvassdr. Sandfjordvassdr??				•	
Jarfjordvassdr.		SFT		•	
Sudajåkka		?		?	

Map showing the potential reference rivers (to be included in final report)

Figur 7. Potential reference rivers including rivers presented in Lyche Solheim et al. (2003) which is indicated as not at risk according to the results from the Characterization projects. Other rivers suggested in appendix R1 will be checked and included in the map before finalizing the report.

With good variance estimates monitoring environmental changes or pollution effects could be done with much lower effort through methods based on modelling. However, such estimates are generally missing. Therefore, we recommend, initially, that 20 sites of each type (altitude x chemistry x river-size) should be selected per eco-region. Most types are represented in only two or three eco-regions, but all eco-regions should be represented if possible. The selected types should be represented by at least five sites from each river, meaning that maximum four rivers per type and eco-region are included in the monitoring program. Priority should be given to rivers with more than one river-type present.

The number of "types" varies between quality elements. **Tabell 9** presents the typology criteria of importance for each quality element, followed by the subsequent number of types and total number of sites that should be included in this first intensive phase of monitoring of reference sites.

Tabell 9. Monitoring of reference conditions, Rivers: Recommendation on how many sites (optimal and minimum) that should be included in the first phase (three years). The typology criteria are presented in Lyche Solheim et al. (2003) and Lyche Solheim & Schartau (2004). The optimal numbers of sites and the minimum number of sites are based on 20 sites per river type, respectively 10 sites per river type (see statistical analyses above). Very small rivers are not included in the minimum design.

Quality element	Typology criteria	# River types[2]	# sites, optimal	# sites, minimum
Benthic algae	4 Eco (E/W, C, N1, N2), 3 Altitude (L, B, H), 6 Chemistry (3 alk x 2 org), 1 Size (S/M/L)	23	460	230
Macroinvertebrates	5 Eco (E, W, C, N1, N2), 3 Altitude (L, B, H), 6 Chemistry (3 alk x 2 org), 2 Size (VS, S/M/L)[1]	58	1160	290
Fish	5 Eco (E, W, C, N1, N2), 3 Altitude (L, B, H), 4 Chemistry (2 alk x 2 org), 2 Size (VS, S/M/L)[1]	48	960	240
Water chemistry[3]			232	116

[1] The macroinvertebrate and fish community of rivers <10 km2 (VS: very small) may be significantly different from larger rivers. We recommend including a number of very small rivers in the reference network (optimal design).
[2] Number of river types are based on an assumption that all prioritized river types presented in **Tabell 6** *is represented among non-impacted rivers in Norway.*
[3] For chemical monitoring we suggest to include one site per river-type per river (in average one sampling station per 5th sites).

3.2.7 Cost estimate rivers

Alternative budgets including man-power and direct costs (travelling, equipments etc.). The budgets are based on an initial, intensive sampling of all selected sites for three subsequent years and yearly average costs (in 1000 NOK) are given. All costs presuppose co-ordination of the fieldwork for all quality elements and rivers. Hyromorphological surveys are only included once during the three year period and yearly average costs are stipulated. For chemical monitoring we suggest to include one site per river-type per river (in average one sampling station per 5th sites).

Tabell 10. Cost estimate rivers

Optimal design: 1 yearly sample of benthic algae (quantitative+qualitative), 2 yearly samples of macroinvertebrates (qualitative), 1 yearly sample of fish (including age analyses).		
Activity	**Costs per site In 1000 NOK**	**Total costs In 1000 NOK**
Fieldwork benthic algae	2,3	1058
Fieldwork macroinvertebrates	4,6	5336
Fieldwork fish	2,3	2208
Fieldwork water-chemistry	2,4	557
Hydromorphological survey	1,5	1740
Lab analyses/reporting benthic algae	4,0	1840
Lab analyses/reporting macroinverteb	4,6	5336
Lab analyses/reporting fish	2,9	2784
Analyses/reporting water chemistry	14	3248
Reporting hydromorphology	2	2320
Temperature logger	?	
Limnigraph	?	
Other field-equipments		90
Co-ordination and admin.		2652
Total costs excl VAT		29168
25% VAT		7292
Total costs incl VAT		**36461**

Minimum design: 1 yearly sample of benthic algae (quantitative+qualitative), 2 yearly samples of macroinvertebrates (qualitative), 1 yearly sample of fish (including age analyses).		
Activity	**Costs per site In 1000 NOK**	**Total costs In 1000 NOK**
Fieldwork benthic algae	2,3	529
Fieldwork macroinvertebrates	4,6	1334
Fieldwork fish	2,3	552
Fieldwork water-chemistry	2,4	139
Hydromorphological survey	1,5	435
Lab analyses/reporting benthic algae	4,0	920
Lab analyses/reporting macroinverteb	4,6	1334
Lab analyses/reporting fish	2,9	696

Analyses/reporting water chemistry	14	812
Reporting hydromorphology	2	580
Temperature logger	?	
Limnigraph	?	
Other field-equipments		75
Co-ordination and admin.		741
Total costs excl VAT		8147
25% VAT		2037
Total costs incl VAT		**10184**

3.2.8 Remaining issues rivers

Further need and possibilities for statistical testing
Despite some general knowledge on temporal and spatial variability in biological data quantitative information on natural variance and the contribution from each of the variance components is very sparse. Few, if any, existing datasets are suitable for this purpose. Still, some datasets may be used for assessing one or several variance components:

- The database on macroinvertebrates from Norwegian rivers (>300 rivers, 1400 sites): After excluding impacted sites and correcting the data for varying sampling effort this dataset may be used for assessing spatial variance (within and between river types) in species composition and in various diversity indices.
- Time-series on benthic algae (species composition, abundances), macroinvertebrates (species composition, abundances) and fish (abundances) from Atna River: So far the temporal variance has been assessed in a qualitative way. In addition these datasets (two different river types) may be used for quantification of year to year variance.

Further work on selection of river sites

- All river types are represented with too few sites. This is especially true for the IC-types R-N1 – R-N4 and R-N9 as well as other sensitive (eutrophication and acidification), national types. Additional river sites should be selected from the complete and updated dataset from the Characterization projects. The selection of reference river-sites should also involve the authorities at the county and community level.
- Glacier impacted rivers has not been prioritized so far. This is a river type which is assumed to be especially sensitive to climate changes. Therefore inclusion of glacier impacted rivers in the reference network should be considered.
- The typology of the suggested sites (river-sections) has to be validated as far as possible against monitoring data (the Characterization is based mainly on geology and to a lesser degree on chemical data).
- Ecological status of acidified rivers (* in 6.Vedlegg B.) has to be validated against monitoring data.
- Info about existing monitoring data/data from surveys and info NVE stations for water-flow registrations has to be completed (c.f. **Table R2**).
- Within the suggested river-sections sampling localities has to be selected based on experience from existing studies, local knowledge and inspection of the rivers.

Mulig gevinst ved samordning med eksisterende nasjonal overvåking?

4. Coastal waters

4.1 Methods coastal waters

4.1.1 Short description of existing data sets

Mapping of distribution and abundance of marine organisms in Norwegian coastal waters has taken place for more than a century, an activity primarily performed by the universities. Over the last decades, however, marine organisms like macroalgae on hard substrates and marine invertebrates inhibiting soft-sediments, have been used in studies of anthropogenic effects, mainly related to pollution-induced disturbances of the communities. These kind of investigations are in most cases investigations of local point source discharges, where the majority of study sites are situated along transects in the vicinity of the discharge, and only one or very few sites are used as reference (=high status) sites. In the marine environment there is for many areas a lack of biological and chemical data for high status sites as the focus for monitoring programs has historically been centered on polluted areas.

The marine ecosystems are currently challenged by an increased human activity in most coastal areas world-wide. Large scale effects of pollution, physical disturbance and possible changes in the marine communities related to changes in climatic conditions, call for proper mapping and monitoring of the marine resources and the biological diversity in coastal waters.

Acknowledgement of the need for a national overview of the marine species present in Norwegian coastal waters resulted in a catalogue published in 1997 (Brattegard & Holthe 1997). This catalogue contains almost 4000 species and span from phytoplankton to fish. Over the last few years there has, both nationally and internationally, been an increase in initiatives related to mapping and monitoring of marine biological diversity, proposals for marine protected areas and establishment of larger mapping and monitoring programs. On top of these activities and initiatives comes the work needed for implementation of the WFD. It is therefore a need for careful planning and co-ordination of these various activities in order to obtain a cost-effective mapping and monitoring systems suitable for the purposes of the various programs.

4.1.2 Datasets on potential reference sites

For some water types the information required for testing of differences in biological composition of quality elements will be available from previous studies or current monitoring programs. In Norway, the main coastal monitoring program which includes elements to be use in the WFD work is the Coastal Monitoring Programme, which was intiated in 1990 (Moy et al. 2002). This program mainly covers the Skagerrak area. **However, for most of the water types along the Norwegian coast, new surveys will be needed in order to produce descriptions of reference conditions for parameters like number of species, species diversity and species composition for the relevant biological elements (phytoplankton, macroalgae and soft-sediment invertebrates).** An accurate description of the reference condition, which takes into account the degree of natural variation within the various habitats present, will be the main part of the future schemes to be used for the classification system.

4.1.3 Chemical and biological datasets used for statistical testing and recommendations

The dataset used for statistical testing (Power analyses) is data for soft-bottom invertebrates from the Coastal Monitoring Programme (Moy et al. 2002). This contains data collected each year from 1990-2000.

4.1.4 Brief description of methods used for statistical testing

We used the software MONITOR 6.2 for calculation of number of sites and replicates necessary to discover trends in the data. The program is distributed for free at the Internett (http://www.mp2-pwrc.usgs.gov/powcase/monitor).

4.2 Results coastal waters

4.2.1 Selection of most important water body types

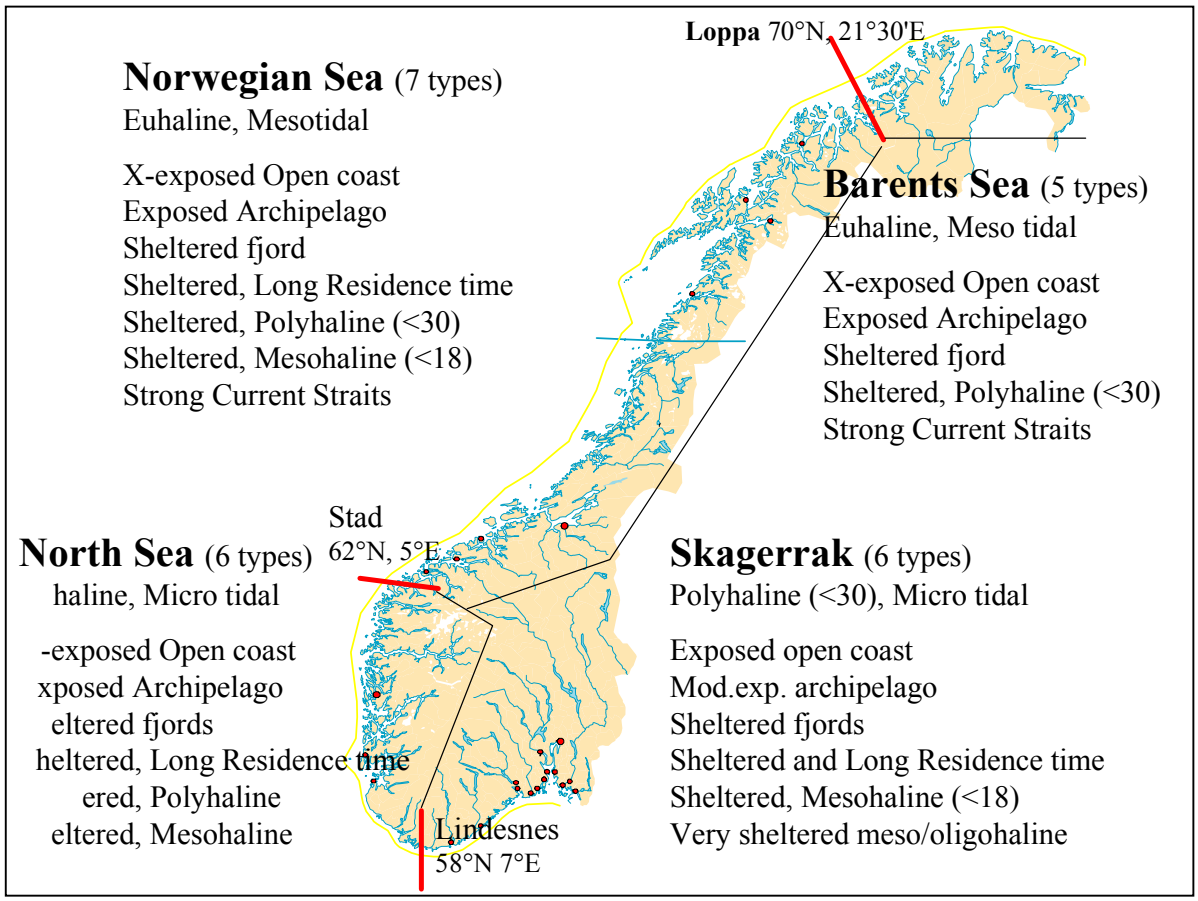
In the WFD the water quality and ecological status are based on deviation from reference conditions in reference areas, i.e. areas where the there are no, or only minor effects of disturbance from human activities on the marine populations and communities. As a basis for description of the marine communities along the coast and expected differences in reference conditions, a typology system has been developed (Moy et al. 2003). The system suggests 23 different water types along our coast, mainly based on factors like wave exposure, tidal range, salinity and oxygen conditions, see

. In addition, for the two northernmost ecoregions straits with strong currents have been proposed as a separate water type.

The next step in this work is to assess and possibly verify the existence of each of the suggested water types. This testing will be based on the biological quality elements recommended for use in the WFD. Only water types that are significantly different, with regard to biological parameters like species diversity and community composition, will be retained. The reference conditions in the various types will also set the background for developing classification schemes for the various coastal water types. This classification system, and the description of ecological status within an area, will be based on deviation from reference conditions.

A proper description of the reference conditions in each water type is therefore needed to enable:

- the necessary testing for real differences between water types with regard to biological quality elements
- the establishment of classification schemes for the various water types, which is based on degree of deviation from reference conditions for the biological parameters used



Figur 8. Proposed typology for the Norwegian coastal waters. 4 ecoregions and 23 different water types are suggested (Moy et al. 2003).

4.2.2 Occurrence of reference sites in different regions and types

In order to perform and establish a good description of the reference conditions there is a need for a certain amount of reference sites within each water type. For some water types the information required for testing of differences in biological composition of quality elements will be available from previous studies or current monitoring programs. **However, for most of the water types along the Norwegian coast, new surveys will be needed in order to produce descriptions of reference conditions for parameters like number of species, species diversity and species composition for the relevant biological elements (phytoplankton, macroalgae and soft-sediment invertebrates).** An accurate description of the reference condition, which takes into account the degree of natural variation within the various habitats present, will be the main part of the future schemes to be used for the classification system.

The development of classifications systems is challenging. Natural biological systems very often show a high degree of variation, both within and between years and also within the same habitat and geographical range. In addition, sampling induced variation need to be accounted for. When biological samples are taken from populations and communities, parameters like sampling method (eg. type of sampling equipment used, sample size), sample

processing (eg. sieving system, sample preservation), choice of sampling depth, habitat (eg. coarse sand or fine clay), season, weather conditions etc. are important factors for the biological parameters (i.e. number of species and community composition) obtained.

Collection of biological samples are often time consuming and expensive. For many of the suggested water types in Norway there is a lack of data suitable to establish reference conditions for the biological element required. However, in cases where such data already exist, it is important to use these data to reduce the amount of work needed to be done and also to supply and verify new data that are collected.

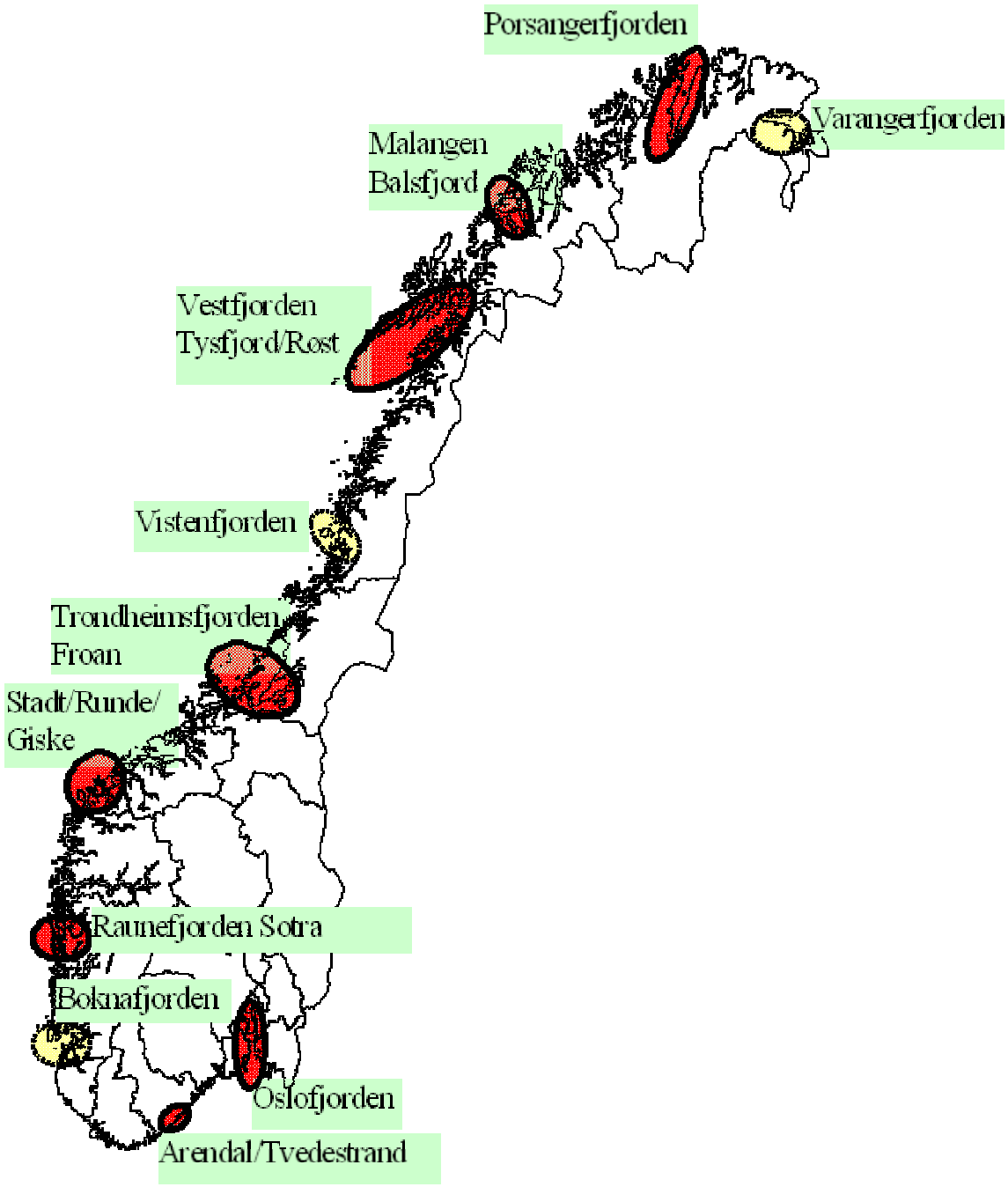
In Norway there is also a proposal for a new program for monitoring of marine biodiversity along the coast, and several of the biological elements to be used in this program are similar to elements to be utilised in the WFD work. A high degree of co-ordination, and possible overlap in areas and sites to be investigated is therefore important and of benefit for both programs. Since there is also an initiative for establishment of new marine protected areas in Norway, it would be preferable to establish study and monitoring sites within these areas.

The proposed areas for the national program for monitoring of marine biodiversity in Norway (Nygaard et al. 2004) are shown in **Figur 9**.

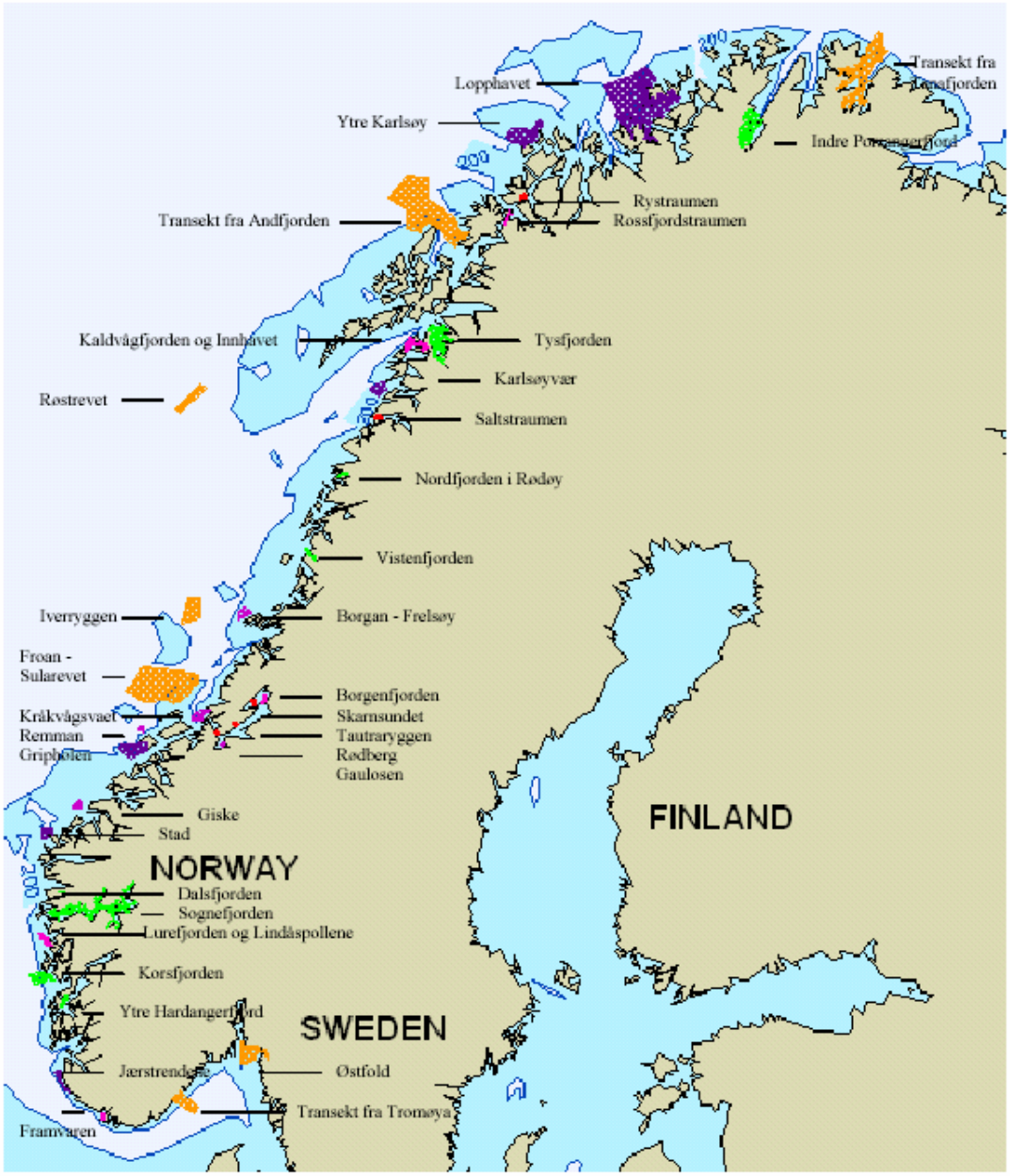
In the design of this program the areas proposed for marine conservation (**Figur 10**) were also taken into consideration, and where possible overlap was attained.

In addition to these two initiatives of relevance for the design of a monitoring program for Norwegian reference sites connected to the WFD, there is a proposal for a European network of locations for a large-scale, long-term marine biodiversity research in Europe (**Figur 11**).

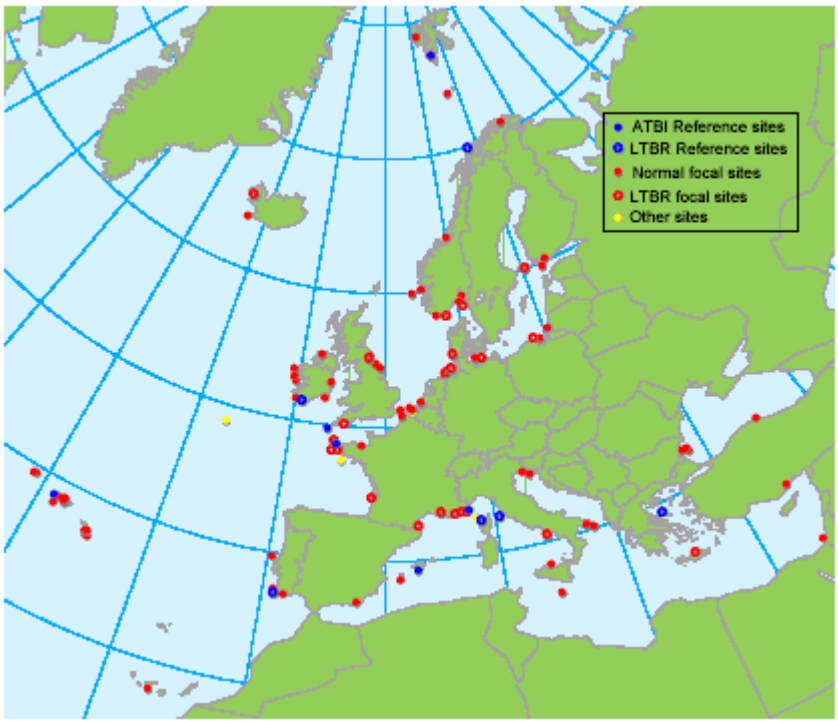
Since all these marine biological monitoring initiatives are related and selection of locations are partly overlapping it is important to obtain as much overlap as possible to reduce the total cost of running the programs.



Figur 9. Proposed areas for monitoring of marine biodiversity in the Norwegian coastal zone. Red areas: main areas; Yellow areas: alternative areas.



Figur 10. Proposal for marine protected areas in Norway (Skjoldal et al. 2003). In the map six different categories of areas are indicated. 1. Polls (light pink), 2. sound with strong current (red), 3. Special shallow areas (pink), 4. Fjords (green), 5. Open coastal areas (bluish pink), 6. Transects coast- open ocean (orange). Depth contour 200 m is also given.



Figur 11. From the BIOMARE-program: proposed sites for European marine biodiversity reference sites. ATBI = All Taxon Biodiversity Inventory, LBTR= Long-Term Biodiversity Research. Blue sites have low anthropogenic influence. Red sites are suitable for effect studies of low level anthropogenic influence. (From Warwick et al. 2003).

4.2.3 Statistical testing and recommendations of number of sites per type

Estimating temporal trends in plant and animal populations is a common goal of biologists and managers and gives an indication of changes in status within the different areas monitored. Trends are typically inferred from data on abundance, number of species or diversity made on sampling locations over time. Trends represent the sustained patterns in data that occur independently of cycles, seasonal variations, and irregular fluctuations in data. A common problem in trend detection is that sources of "noise" in data obscure the "signal" associated with ongoing trends. The probability that a monitoring program will detect a trend in sample data when the trend is occurring, despite the "noise" in the data, represents its **statistical power**. Although statistical power is central to every monitoring effort, it is rarely assessed. Consequences of ignoring it include collection of data insufficient to make reliable inferences about population trends, or collection of data in excess of what is needed.

Estimates of statistical power of population monitoring programs depends on

- the number of locations monitored
- the number of replicates per location
- variation in data within sites (standard deviation)
- the duration of the monitoring
- the interval of monitoring
- the magnitude and nature of ongoing population trends (eg. linear or exponential)
- variation in trends between locations

- the significance level associated with trend detection (α-level)
- and several other factors.

Because these factors interact in complex ways to determine the capacity of a monitoring program to detect trends in populations, such basic questions of "how many plots should I monitor" or "how often should I conduct surveys" rarely have intuitive answers. However, in order to have a cots-effective monitoring program with high statistical power to detect trends it is important to evaluate how each component influences the monitoring program's power to detect trends.

Statistical power must be calculated for all quality elements based on data from a representative selection of sites from the defined water types. Statistical power will vary between the quality elements and probably also between the different water types. So far power analysis have only been calculated for soft bottom fauna based on a limited data set from ecoregion Skagerrak. The result is shown in **Tabell 11**.

Tabell 11. The probability of finding a decrease or increase in number of species per 0.1 m^2 with varying number of sampling sites and replicate samples on each site

	One site [1)]			*Two sites*			*Three sites* [3)]		*Four sites* [4)]		*Five sites* [5)]	
Repl.	4	8	20	4	8	20	4	8	4	8	4	8
Trend, % per year												
-10	0.95	1.00	1.00	0.54	0.73	0.90	0.96	1.00	1.00	1.00	1.00	1.00
-5	0.56	0.84	0.99	0.33	0.45	0.67	0.65	0.90	0.87	0.98	0.95	1.00
-3	0.31	0.52	0.86	0.19	0.28	0.51	0.40	0.57	0.55	0.79	0.71	0.94
-2	0.20	0.29	0.54	0.16	0.21	0.32	0.24	0.36	0.34	0.54	0.44	0.65
-1	0.12	0.16	0.22	0.12	0.14	0.15	0.17	0.17	0.20	0.22	0.22	0.25
0	0.11	0.11	0.10	0.09	0.09	0.09	0.08	0.08	0.09	0.13	0.11	0.10
+1	0.12	0.17	0.23	0.11	0.12	0.17	0.14	0.18	0.19	0.27	0.19	0.30
+2	0.22	0.33	0.55	0.19	0.25	0.32	0.29	0.39	0.37	0.57	0.46	0.72
+3	0.33	0.61	0.91	0.25	0.33	0.48	0.47	0.64	0.58	0.88	0.77	0.93
+5	0.70	0.94	1.00	0.42	0.54	0.76	0.78	0.95	0.94	0.99	0.99	1.00
+10	1.00	1.00	1.00	0.77	0.90	0.99	1.00	1.00	1.00	1.00	1.00	1.00
No. sample	20	40	100	40	80	200	60	120	80	160	100	200

1) Data from the Norwegian coastal monitoring program; site A05; 2) data from sites A05 + A10; 3) sites A05 + A10 + B05; 4) sites A05 + A10 + B05 + B10; 5) sites A05 + A10 + B05 + B10 + C12

The power analysis show good strength in monitoring number of species. A monitoring design based on 4 stations (sites) with 4 replicate samples, the probability to detect a yearly 5% decrease or increase is strong ($p>0.87$). With 8 replicate samples the strength is increased to $p>0.98$. To detect a 3% change demands 20 replicate samples from one site or 8 replicate samples from 3 or more sites.

To establish a reference network for soft bottom fauna the initial monitoring should include 24 samples/sites from each water type to ensure a minimum data set for calculation of variance. Existing data may of course be included to minimize new sampling effort.

When the initial reference network is established and power analysis for the quality elements are calculated, a subset of these sites may be selected for monitoring.

4.2.4 Statistical testing and recommendations of frequency of observations per site and element

In order to get a handle on the natural variation of the biological quality elements within each water type it will be necessary to have biological data on number of species, diversity and community composition. Initially we have to investigate the possible use of already existing data from the many investigations already performed or still running in Norway. If relevant and good quality data is not available new sampling will be needed. For many areas it will be necessary to collect new samples. Samples need to be taken yearly for a period of 3-5 years in order to establish a baseline for natural variation for each quality element within each area to obtain a reasonable amount of data needed for statistical testing of deviation from reference conditions. When a proper baseline for statistical testing is achieved it may be possible to reduce the sampling frequency.

4.2.5 Selection of elements and sampling frequency

For coastal waters the biological quality elements proposed to be used in the WFD work are **phytoplankton**, **benthic macroalgae**, **angiosperms** (mainly sea grass) and **benthic invertebrate fauna**. Of these elements the benthic macroalgae and benthic invertebrate fauna inhibiting soft-sediments have a long tradition for use in monitoring of health status in coastal waters, while the other elements are not used to the same extent. Phytoplankton is however a good indicator for problems related to eutrophication. Phytoplankton is also important to monitor with regard to accumulation in sea shells and dense algal blooms can be a nuisance for fish farming activities. Blooms of toxic algae may also be a problem for survival of marine organisms in general.

In Norway the populations of sea grass are very patchy distributed and this element may not be suited as a monitoring tool for biological status. The element benthic invertebrate fauna is supposed to be monitored both at hard and soft substrata. The use of soft-bottom invertebrate fauna has a long track record for monitoring purposes, but invertebrate fauna on hard substrates are not frequently used neither nationally or internationally as a monitoring tool. The development of proper tools based on invertebrate fauna on hard substrata will therefore need further work and investigations. The main biological quality elements to be used in the near future in WFD work in Norway will therefore probably be phytoplankton, benthic macroalgae and benthic invertebrates in soft-sediments.

The elements likely to be used for coastal waters in Norway in relation to the WRD work are shown in green colour in Tabell 12. The two more uncertain types (angiosperms and benthic invertebrates on hard substrates are shown in yellow, while fish is not relevant for WFD monitoring in coastal waters and is shown in red.

Tabell 12. Elements likely to be used for WFD monitoring in Norway (green). Elements not yet decided for use are shown in yellow, while fish is not a relevant parameter in our coastal waters

Elements	
Phytoplankton	+
Benthic macroalgae	+
Angiosperms (mainly sea grass)	?
Benthic invertebrates, hard substrates	?
Benthic invertebrates, soft sediments	+
Fish	-
Physico-chemical elements	+
Hydro-morphological elements	+

The elements and parameters most relevant for use in Norway the next few years are listed in **Tabell 13** together with the recommended sampling frequency and sampling season for Norwegian coastal waters.

Tabell 13. Recommended elements, parameters, sampling frequency and sampling seasons for coastal waters.

Element	Parameter	No. of samples year^{-1}	Sampling season
Phytoplankton	Abundance Diversity Composition Biomass Planktonic blooms	20	All year
Macroalgae	Abundance Composition Cover Depth distribution	1	Summer
Benthic invertebrates	Abundance Diversity Composition	1	Spring
Physico-chemical	Thermal conditions Oxygenation conditions Salinity Nutrient conditions Transparency	20	All year
Hydromorphological:	Tidal regime: Direction of dominant currents Wave exposure Morphological conditions: Depth variation Structure and substrate of the coastal bed Structure of the inter-tidal zone	1	Summer

4.2.6 Selection of reference sites

Tabell 14 gives a summary of the areas suggested for use within the different programs described above. The areas suggested for use in the WFD is given in the last column. The number of areas indicated as reference sites for the WFD are higher than for the other programs. **The reason for this is that for the WFD and the proposed classification scheme the reference areas and the composition of the biological quality elements within these high status areas are the basis for the whole classification system and the degree of deviation from reference conditions within each water type is the basis for this system**. An accurate description of the reference conditions for each of the selected biological quality elements is therefore essential. Within biological systems there is a high degree of variation in number of species and composition within the different groups of organisms. In order to use reference conditions as a starting point for classification the degree of natural variation need to be known, ie. there is a need for quantitative data and to know statistical properties like mean number of species and an expression for variance around the mean (like confidence limits). To obtain these numbers a certain amount of background data is necessary, which

means that there is a minimum number of reference sites is needed within each water type. In particular in the initial testing for differences within and between water types there is a need for a minimum number of good quality data for each biological quality element.

Tabell 14. List of suggested coastal reference areas for the WFD work in Norwegian coastal waters.

Areas	National marine biodiversity (2004)	Marine protected areas (2003)	Biomare (2003)	Typology report (2003)	Proposed WFD Reference areas (this report)
18.Varangerfjorden	(+)	-	+	+	+
17. Laksefjorden	-	-	-	+	+
16. Porsangerfjorden	+	+	+	-	+
Magerøy/Lafjorden	-	-	-	+	-
15. Fugløy-Kvænangen	-	-	-	+	+
14. Malangen/Balsfjord	+	+/- (Rystr./Rossfj .-straumen)	+	+	+
13. Vestfjorden – Tysfjord-Røst	+	+	-	-	+
12. Vistenfjorden	(+)	+	-	+	+
11. Trondheimsfjorden – Froan	+	+	+	+	+
10. Stadt/Runde/Giske	+	+	+/-	-	+
9. Dalsfjorden	-	+	-	+	+
Sognefjorden	-	+	-	+	-
8. Fensfjorden	-	-	-	-	+
7. Raunefjorden/Sotra	+	+/- (Korsfjorden)	+/-	+	+
6. Boknafj.-Erfjorden	(+)	-	-	+	+
5. Lista	-	-	+	+	+
4. Mandal	-	-	-	-	+
3. Kristiansand					+
2. Arendal/Tvedestrand	+	+/- (Tromøy)	+	+	+
1. Risør-Sandnesfj.	-	-	-	+	+
Oslofjorden*)	+	+/- (Hvaler)	+	-	-

*) The whole Oslofjord area is at risk for not reaching good or high status. However, this is a large, important area; necessary to establish reference conditions. Data from the Swedish West Coast may be applied to describe reference conditions. This will be investigated further.

The suggested marine reference areas for use in the WFD are shown in **Figur 12**. In the planning for suitable areas to employ as reference areas several factors are taken into consideration. These are mainly based on knowledge of the biological communities present and there status with regard to possible effects of human disturbance. A separate project is currently identifying areas at risk for not reaching good status or reference status (SFT), but data from this project was not available to us in this project.

In addition it is important to make use of already existing data available and suitable as reference data in the WFD work. Some of the areas proposed may be impacted by biological processes like kelp grazing by sea urchins (especially within less exposed areas from North-Western Norway to Finnmark), and there it may be difficult to find macroalgae communities that are not affected by disturbance. The invertebrate fauna in several soft-sediments areas

along the coast will be affected by bottom-trawling in and identification and mapping of these areas will be necessary before final reference locations can be determined more accurately.

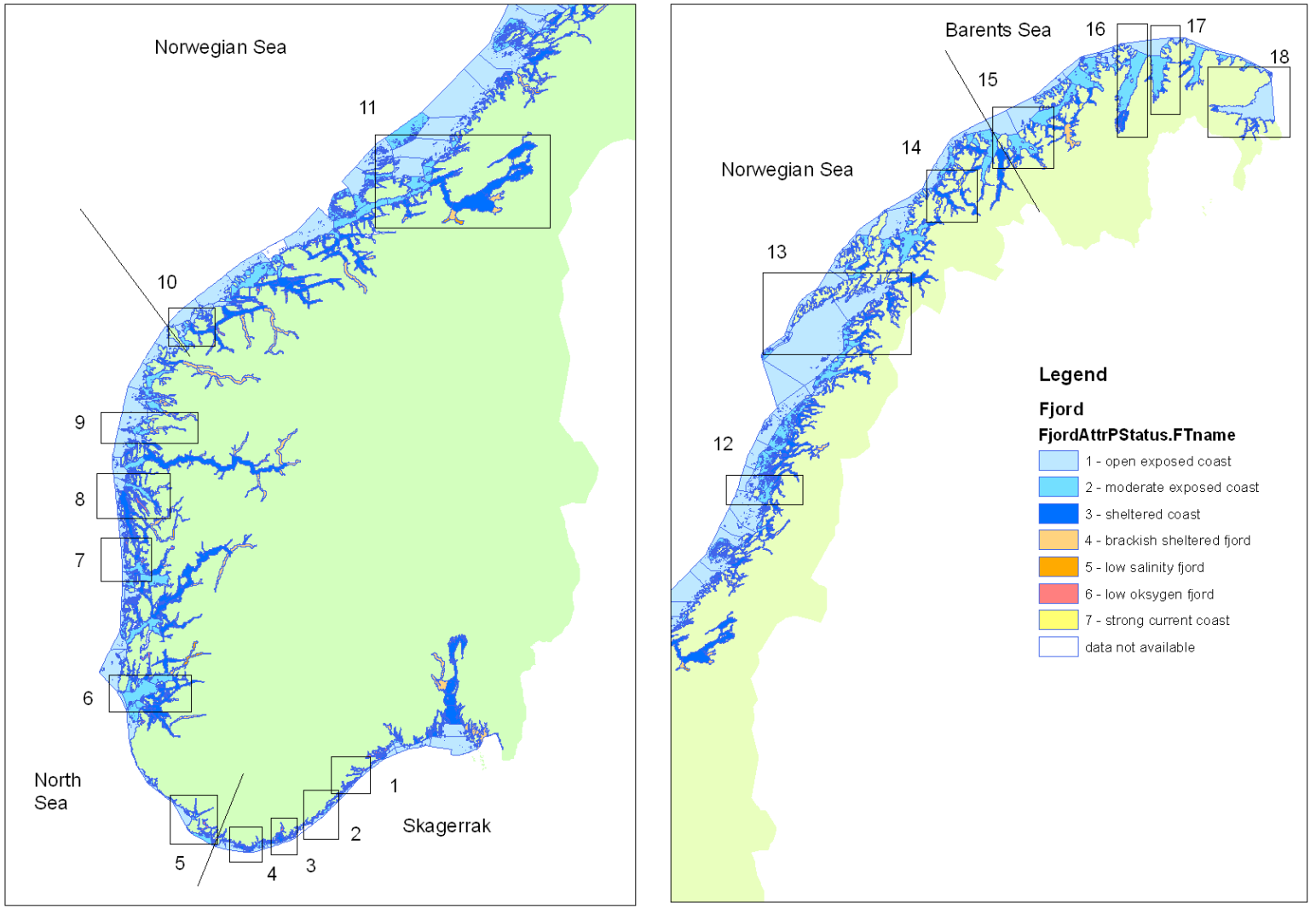
Within each reference area samples shall be taken from the outer exposed area, the moderate exposed area, sheltered coast/fjord, fjords influenced by freshwater and fjords with long residence time. In **Figur 12** these different habitats are indicated as squares within each reference area. Within each habitat it is necessary to sample at least 3 sites and take replicate samples within each site for the biological elements.

At present we do not have full data sets for each quality element that will be needed to describe reference conditions for the whole coast. This is particular true for phytoplankton and macroalgae. From the north-western part of Norway to the Barents Sea most of the data needed for description of water types and biological and physico-chemical reference conditions will have to be based on new sampling campaigns. In the short term, expert judgement will be needed for several areas, because of the lack of good data sets.

For the Skagerrak area, and partly for Western Norway, much of the data collected within the National coastal monitoring program and several local monitoring programs can be used as input data to evaluate reference conditions in the various water types.

The 23 water types proposed for Norway has not been tested yet with regard to significant differences in measures like abundance, number of species, community composition (eg. proportion of sensitive and tolerant species) for the most relevant elements (phytoplankton, macroalgae and soft-sediment invertebrates).

The areas suggested as reference areas in the WFD work (Tabell 14, Figur 12) are mainly based on expert judgement and the choice of locations are somewhat preliminary. More precise decisions for final location of sampling sites will be taken when information on already available data are completed and more comprehensive local information is collected and evaluated.



Figur 12. Proposed reference areas (18 areas) for coastal waters related to WFD implementation. These areas will be used to establish reference data for the biological quality elements phytoplankton, macroalgae and soft-sediment benthic invertebrates to confirm or refute the 23 water types proposed for Norwegian coastal waters (Moy et al. 2003). Based on these results the number of reference areas may be reduced (or increased) for future WFD monitoring.

4.2.7 Cost estimate coastal waters

The cost for each water type is estimated to 1.37 mill NOK for each water type (**Tabell 15**). That implies a initial cost for establishing a reference network of 18 areas, each including ca. 4 water types, to be around 100 mill NOK. Since we already have a coastal monitoring program for the Skagerrak-area, some of the sites in this area may be used as reference sites in the WFD. This will reduce the cost given below. For the rest of the coast some of the already existing data from various marine institutions may be used to describe reference conditions, but the investigations into this has not been initiated yet, and the size of a possible reduction in the budget can therefore not be given at the moment.

After reference values are established the running costs for reference monitoring is estimated to be between 20 to 30 mill NOK based on 23 coastal water types.

Tabell 15. Estimated number of sampling sites/transects and sampling cost for one water type in one area.

Quality Element	No. of samples/sites pr. water type	Frequency Sampling / year	Estimated Cost (1000NOK)
Phytoplankton	4 sites	20	320
Macroalgae	4 transects	1	400
Soft bottom fauna	24 samples	1	250
Hydrography, nutrients and hydromorphology	4 sites and 1 vertical profile	22	400
			1370

5. Reference sites in different river basin districts

The different river basin districts to be used for implementing the WFD in Norway should all have a sufficient number of reference sites for all surface water categories. As soon as these districts have been identified by the national authorities, the proposed reference network should be evaluated and revised to ensure the presence of reference lakes, rivers and coastal waters within each district.

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Vedlegg A. Selected reference lakes

Tabell 16. Selected reference lakes. Shades lakes belong to lake types which are not prioritized. The list contains 118 prioritized lakes (non-shaded). Ecoregions indicated by Ø: Eastern, S: Southern, W: Western, M: Central, N: Northern – coastal, F: Northern, inland. Lake size indicated by 1: small lakes 0.5-5 km2 or 2: > 5 km2. Altitude regions indicated by: L: Lowland, S: Boreal, F: Highland. The geological lake types are identified according to Lyche-Lyche Solheim and Schartau 2004 and are consistent with the IC-types and other national types.

Geological lake type	Watershed no.	NVE No.	County	Name	MS_CD	Ecoregion, altitude, size
					water body id	
Very low alk., clear						
	310.5A	33258	Hedmark	Store Gunnarsjøen	31033258L	Ø1S
	002.LE	126	Hedmark	Atnsjøen	002126L	Ø2S
	104.D6Z	34660	Oppland	Svartdalsvatnet	10434660L	Ø1F
	002.DJ1C	231	Oppland	Rondvatnet	002231L	Ø1F
	002.DJCB	233	Oppland	Mjogsjøen	002233L	Ø1F
	002.DHEB	29185	Oppland	Nedre Søvertjørni	00229185L	Ø1F
	002.DFJ	146	Oppland	Bygdin	002146L	Ø2F
	015.NG	392	Buskerud	Storekrækkja	015392L	Ø1F
	016.L2AB	40	Telemark	Urdevatnet	01640L	S1F
	016.G5C2B2C	109	Telemark	Viuvatnet	016109L	S1F
	019.F2F	1293	Telemark	Sandvatnet	0191293L	S1S
	019.H12	1277	Telemark	Skredvatn	0191277L	S2S
	019.A1Z	10623	Aust-Agder	Assævatnet	01910623L	S1L
	019.12Z	10538	Aust-Agder	Longumvatnet	01910538L	S1L
	019.AB11	1270	Aust-Agder	Rore	0191270L	S2L
	022.CA3	10727	Vest-Agder	Myglevatnet	02210727L	S1S
	048.B1	1701	Hordaland	Sandvinvatnet	0481701L	V1L
	050.A3	1905	Hordaland	Eidfjordvatnet	0501905L	V1L
	062.GB	2090	Hordaland	Oppheimsvatnet	0622090L	V1S
	062.H3	2091	Hordaland	Myrkdalsvatnet	0622091L	V1S
	085.A	28328	Sogn og Fjordane	Svardalsvatnet	08528328L	V1S
	082.A3	1639	Sogn og Fjordane	Hovlandsvatnet	0821639L	V1S
	085.D	1754	Sogn og Fjordane	Endestadvatnet	0851754L	V1S
	083.C1	1650	Sogn og Fjordane	Hestadfjorden	0831650L	V1S
	072.B110	1497	Sogn og Fjordane	Vassbygdvatnet	0721497L	V1S
	087.1C	28120	Sogn og Fjordane	Traudalsvatnet	08728120L	V1S
	082.C3	1641	Sogn og Fjordane	Hovlandsdalsvatnet	0821641L	V1S
	084.C11	1733	Sogn og Fjordane	Movatnet	0841733L	V1S
	089.B1	1807	Sogn og Fjordane	Hornindalsvatnet	0891807L	V2L
	074.B11	1571	Sogn og Fjordane	Årdalsvatnet	0741571L	V2L
	088.B11	1802	Sogn og Fjordane	Strynevatnet	0881802L	V2L
	083.C31	1648	Sogn og Fjordane	Viksdalsvatnet	0831648L	V2S
	083.E0	1649	Sogn og Fjordane	Haukedalsvatnet	0831649L	V2S
	084.E1	1734	Sogn og Fjordane	Jølstravatnet	0841734L	V2S
	093.2C	31047	Møre og Romsdal	Blæjevatnet	09331047L	V1F
	097.7B	1955	Møre og Romsdal	Fitjavatnet	0971955L	V1L
	094.B	1934	Møre og Romsdal	Bjørkedalsvatnet	0941934L	V1L
	103.BE	1987	Møre og Romsdal	Ulvådalsvatnet	1031987L	V1S

	102.112	31309	Møre og Romsdal	Store Hestevatnet	10231309L	V1S
	099.1B	1976	Møre og Romsdal	Eidsvatnet	0991976L	V1S
	101.5B	1982	Møre og Romsdal	Brusdalsvatnet	1011982L	V2L
	111.BC	33992	Møre og Romsdal	Øvre Neådalsvatnet	11133992L	M1F
	139.ECB	716	Nord-Trøndelag	Storgåsvatnet	139716L	M1F
	135.2A	36780	Sør-Trøndelag	Grovlivatnet	13536780L	M1L
	116.2Z	36436	Møre og Romsdal	Skardvatnet	11636436L	M1S
	135.3C0	36727	Sør-Trøndelag	Skjerivatnet	13536727L	M1S
	138.BA1Z	40844	Nord-Trøndelag	Bjørfarvatnet	13840844L	M1S
	308.2CAC	1149	Nord-Trøndelag	Midtre Blåfjellvatnet	3081149L	M1S
	308.3B	1141	Nord-Trøndelag	Arvatnet	3081141L	M1S
	308.2CD	41040	Nord-Trøndelag	Snaufjellvatnet	30841040L	M1S
Very low alk., humic						
	311.EC1B	1363	Hedmark	Arasjøen	3111363L	Ø1S
	120.2E	2524	Sør-Trøndelag	Austvatnet	1202524L	M1S
Low alk., clear						
	002.K6AB	242	Hedmark	Møklebysjøen	002242L	Ø1F
	311.J11	1348	Hedmark	Femunden	3111348L	Ø2S
	311.DB10	1351	Hedmark	Engeren	3111351L	Ø2S
	015.PC	395	Buskerud	Langesjøen	015395L	Ø2F
	015.5B	433	Vestfold	Hallevatnet	015433L	Ø1L
	016.K3E	18827	Telemark	Dargesjåen	01618827L	S1F
	016.K3D	39	Telemark	Fjellsjåen	01639L	S1F
	039.4B	2039	Rogaland	Storavatnet	0392039L	V1L
	039.3B	2038	Rogaland	Aksdalsvatnet	0392038L	V1L
	039.5B	2040	Rogaland	Storevatnet	0392040L	V1L
	040.2	23007	Rogaland	Hilleslandsvatnet	04023007L	V1L
	039.80	22815	Rogaland	Tuastadvatnet	03922815L	V1L
	041.1C	2041	Rogaland	Stakkastadvatnet	0412041L	V1L
	035.1B	1859	Rogaland	Hetlandsvatnet	0351859L	V1L
	033.1B	1679	Rogaland	Vostervatnet	0331679L	V1S
	032.4A22	23082	Rogaland	Nordvatnet	03223082L	V1S
	016.N3A	43	Hordaland	Litlosvatnet	01643L	V1F
	016.M7B	42	Hordaland	Valgardsvatni	01642L	V1F
	062.G3	2089	Hordaland	Lønavatnet	0622089L	V1L
	059.3B	2060	Hordaland	Askevatnet	0592060L	V1L
	082.3A	1643	Sogn og Fjordane	Langesjøen	0821643L	V1L
	083.D3	1653	Sogn og Fjordane	Lauvavatnet	0831653L	V1S
	084.CB	1736	Sogn og Fjordane	Holsavatnet	0841736L	V1S
	088.1B	27288	Sogn og Fjordane	Oldevatnet Sør	08827288L	V2L
	101.6B	1983	Møre og Romsdal	Engsetvatnet	1011983L	V1L
	097.72Z	31509	Møre og Romsdal	Andestadvatnet	09731509L	V1L
	095.D	1945	Møre og Romsdal	Vatnevatnet	0951945L	V1L
	094.6B	1941	Møre og Romsdal	Rotevatnet	0941941L	V1L
	127.B4AB	928	Nord-Trøndelag	Store Høysjøen	127928L	M1S
	139.BE	694	Nord-Trøndelag	Sandsjøen	139694L	M1S
	173.B1B	1030	Nordland	Rundtindvatnet	1731030L	N1F
	163.E8Z	44473	Nordland	Straitasjavri	16344473L	N1F
	180.4Z	47909	Nordland	Reppvatnet	18047909L	N1L
	181.1	48048	Nordland	Storvatnet	18148048L	N1L
	189.B	2362	Troms	Saltvatnet	1892362L	N1L
	194.6C	50879	Troms	Kapervatnet	19450879L	N1S
	218.AAC	59237	Finnmark	Litle Havvatnet	21859237L	N1F
	213.6D	55834	Finnmark	Øvre Saltvatnet	21355834L	N1F

	234.GBE1D	57475	Finnmark	Duolbajavri	23457475L	F1F
	234.F3C	62396	Finnmark	Lævvajavri	23462396L	F1F
	234.GBCBB	57607	Finnmark	Guotkujavrit	23457607L	F1S
	234.L5	2276	Finnmark	Gavdnjajavri	2342276L	F1S
	234.F1AZ	62290	Finnmark	Baisjavri	23462290L	F1S
Low alk., humic						
	002.DAA32	141	Akershus	Hurdalsjøen	002141L	Ø2S
	313.3AD	368	Hedmark	Storbørja	313368L	Ø1S
	002.G6D5	238	Hedmark	Eidsmangen	002238L	Ø1S
	313.C	353	Hedmark	Skjervangen	313353L	Ø2L
	002.JBB11	162	Hedmark	Ossjøen	002162L	Ø2S
	002.DAB2C	4789	Oppland	Langen	0024789L	Ø1S
	015.EB	379	Buskerud	Vatnebrynnvatnet	015379L	Ø1S
	012.CC7B	7073	Buskerud	Langevatnet	0127073L	Ø1S
	012.DD	7241	Buskerud	Buvatnet	0127241L	Ø1S
	016.4AB	112	Telemark	Kilevatn	016112L	S1L
	016.CA1B	13505	Telemark	Reskjemvatnet	01613505L	S1S
	066.4	26360	Hordaland	Ølvatnet	06626360L	V1S
	159.91Z	44273	Nordland	Grønåsvatnet	15944273L	M1L
	185.1B	1217	Nordland	Alsvågvatnet	1851217L	N1L
	180.62B	2534	Nordland	Urdvatnet	1802534L	N1L
	170.5DC	1001	Nordland	Kjerrvatnet	1701001L	N1S
	163.D1B	806	Nordland	Kjemåvatnet	163806L	N1S
	200.6B	1713	Troms	Skogsfjordvatnet	2001713L	N2S
	238.5B	2430	Finnmark	Oksevatnet	2382430L	F1F
	247.4G	64482	Finnmark	Store Skardvatnet	24764482L	F1F
	224.AB	60095	Finnmark	Vuoååojavri	22460095L	F1F
	212.D	2173	Finnmark	Ladnetjavri	2122173L	F1S
	246.F1D	2455	Finnmark	Store Spurvvatnet	2462455L	F1S
Moderate alk., clear						
	002.JD1	125	Hedmark	Storsjøen	002125L	Ø2S
	160.710	43877	Nordland	Storvikvatnet	16043877L	N1L
	160.43B	785	Nordland	Markavatnet	160785L	N1L
	162.1B	800	Nordland	Valnesvatnet	162800L	N1S
	177.4Z	48261	Troms	Storvatnet	17748261L	N1S
	189.2B	2365	Troms	Blåfjellvatnet	1892365L	N1S
	196.5B	2417	Troms	ytre Fisklausvatnet	1962417L	N2S
	196.F3	2399	Troms	Litle Rostavatnet	1962399L	F2S
	234.GBG10	2279	Finnmark	Iesjavri	2342279L	F2S
Moderate alk., humic						
	165.2B	834	Nordland	Soløyvatnet	165834L	N1L
	194.5B	2385	Troms	Storvatnet	1942385L	N1S
	196.2C	2416	Troms	Finnfjordvatnet	1962416L	N2L
	193.C	2376	Troms	Skøvatnet	1932376L	N2S
	196.CAB	2404	Troms	Takvatnet	1962404L	F2S
	240.4	63092	Finnmark	Andersbyvatnet	24063092L	F1F
	240.2Z	63116	Finnmark	Langsmedvatnet	24063116L	F1S

Vedlegg B. Potential reference rivers

Tabell 17. Potential reference sites for Norwegian rivers. The water-body code is identical with the MS-code used in the Characterization project. One water-body may constitute of several small watercourses of lower orders. River types not included among common Norwegian river types in Lyche Solheim & Schartau (2004) is indicated and described in the foot-notes. The IC-types are originally restricted to Eastern, Western and Central eco-regions. Eco-regions: E: Eastern, W: Western, C: Central, N1: Northern, coastal parts, N2: Northern, inland parts. Bold types: Highly prioritized river types (see main text). The IC-types R-N2, R-N3, R-N5, R-N7 and R-N9 has no lower alkalinity/calcium limit, but, except for Norway, few sites with very low alkalinity are available in the Northern GIG. Norway should therefore include these sites (in brackets) in the intercalibration exercise with precaution. The list of potential reference sites may be extended after further investigation of the output from the Characterization project. * Uncertain Ecological status due to acidification of the area – need a more thorough check. ? Not typified. Sites not at risk?

Watercourse	Watercourse of lower order	Water-body	Eco-reg	IC type	Norw type
Haldenvassdr	**Hafsteinelva Hemneselva Hølandselva**	**001003610R**	**E**	**R-N9**	**10**
Glomma/Osa	**Nordre Osa Ossjøen**	**002029158R**	**E**	**R-N9**	**10**
Glomma/Atna	Atna	002064313R	E	(R-N5)	8
	Atna	**002040087R**	**E**	**R-N5**	**9**
	Atna	**002062518R**	**E**	**R-N5**	**9**
	Atna	002062523R	E	(R-N7)	15
Glomma/Sjoa	**Nedre Sjodalsvt Sjoa**	**002092768R**	**E**	**R-N5**	**9**
	Sjoa	**002092058R**	**E**	**R-N5**	**9**
Glomma/Håelva	**Håelva**	**???**	**E**	**R-N9**	**10**
Sandvikselva	**Lomma**	**008000106R**	**E**	**R-N9**	**10**
Begna????			E		
Gudbranddalslågen/Otta	**Frøysa**	**002103XXXR**		**R-N7**	**16?**
	Måråi	**002103XXXR**	**E**	**R-N7**	**16?**
	Vulu	**002103XXXR**	**E**	**R-N7**	**16?**
	Tora	**002103XXXR**	**E**	**R-N7**	**16?**
	Ostri	002103400R	E		17
	Åfotgrovi	002103XXXR	E		17
	Tundra	002103XXXR	E		17
	Skjøli	002103XXXR	E		17
	Bøvra	002110(973)R	E		17
Trysilvassdr	**Røa**	**???**	**E**	**R-N9?**	**10?**
	Mugga	**???**	**E**	**R-N9**	**10**
Skiensvassdr	*Skiensvassdr (SW lower parts)*		E	?	?
	Skiensvassdr (upper parts)		E	?	?
Osvassdr			W	?	?
Tyssevassdr			W	?	?
Etne			W	?	?
Eidfjordvassdr/	Veig	050003962R	W	(R-N7)	15

Veig					
Vossovassdr*	Raundalselvi	062001026R	W	(R-N5)	8
	Raundalselvi Kleivelvi	062001019R	W	(R-N7)	15
Ekso			W	?	?
Yndesdalsvassdr			W	?	?
Aurlandsvassdr			W	?	?
Lærdalselva	Kuvella		W	?	?
	Other?		W	?	?
Nausta*	Nausta	069000896R	W	?	?
Gaularvassdr*	Gaula Hestadfjorden	083001370R 083001370R	W	?	?
Oldenvassdr	Oldenvassdraget Oldenvatnet	088000001R 088000001R	W	?	?
	No name	088001152R	W	?	?
Rauma	Rauma	103003329R	W		8[1]
	Rauma	103001937R	W	(R-N7)	15
	Lesjaskogvatnet Rauma	103001958R	W	(R-N7)	15
Surna	*Surna, upstream regulations*		C	?	?
	Others (second order rivers)		C	?	?
Driva	Driva	109006186R	C		13
Stjørdalsvassdr	**Austre Tverrsona**	**124001963R**	**C**	**R-N5**	**9**
	Feren	**124000449R**	**C**	**R-N5**	**9**
	Forra	**124000258R**	**C**	**R-N5**	**9**
	Sona Vestr+Austre Sonvatnet	**124002877R**	**C**	**R-N5**	**9**
Namsenvassdr	**Luru**	**139011896R**	**C**	**R-N2**	**1**
	Namsen	**139000052R**	**C**	**R-N2**	**1**
	Namsen	139041036R	C		6
	Otersjøen Sandøla	**139011251R**	**C**	**R-N5**	**9**
	Sørvatnet (St Namsvatnet)	**139049847R**	**C**	**R-N5**	**9**
	Alma	**139016326R**	**C**	**R-N5**	**9**
	Namsen	139040693R	C		13
	Namsen	139040802R	C		13
	Alma	**139007418R**	**C**	**R-N7**	**16**
	Luru	**139007416R**	**C**	**R-N7**	**16**
Vefsna	**Austre Tiplingen**	**151018702R**	**C**	**R-N5**	**9**
Beiarelva	Beiarelva	161001842R	N1 (C)		18
	Tverråga	161001842R	N1 (C)		18
Skjoma			N1	?	?
Saltdalsvassdr	**Lønselva**	**163005240R**	**N1 (C)**	**(R-N5)**	**9**
	Lønselva	**163001777R**	**N1**	**(R-N7)**	**16**
Målselvvassdr	Målselvvassdraget	196014747R	N2		7
	Rostaelva	**196023642R**	**N2**		**11**
	Rostaelva	**196024001R**	**N2**		**11**
	Rostaelva	**196024614R**	**N2**	**(R-N7)**	**16**
	Rås'tajav'ri	196023643R	N2		18[2]
Reisaelvvassdr	**Njallajåkka Reisavassdraget**	**208000509R**	**N2**	**(R-N9)**	**10**
	Njallajåkka	**208000512R**	**N2**	**(R-N9)**	**10**

	Reisavassdraget				
	Reisavassdraget	**208000513R**	**N2**	**(R-N9)**	**10**
	Reisavassdraget	**208003141R**	**N2**	**(R-N9)**	**10**
	Reisavassdraget	**208003449R**	**N2**		**12**[3]
	Reisavassdraget	**208000523R**	**N2**	**(R-N7)**	**16**
Altavassdr	Kautokeinoelva	212000004R	N2	?	?
	No name	212000064R	N2	?	?
	Bajit Vuoccetjav'ri Cabardasjåkka Duol'bajav'ri Guov'dagãinãdno Jumesjav'ri Kautokeinoelva Vuoccetjåkka Vuolit Vuoccetjav'ri *No name*	212002424R 212002424R 212002424R 212002424R 212002424R 212002424R 212002424R 212002424R 212002424R	N2	?	?
	Guov'dagãinãdno Kautokeinoelva	212005912R 212005912R	N2	?	?
	Cabardasjåkka	212013922R	N2	?	?
	Altavassdraget Duol'bajav'ri Guov'dagãinãdno Lup'pujåkka	212013934R 212013934R 212013934R 212013934R	N2	?	?
Lakselvvassdr	Lãvdnjajåkka	224003317R	N2		4
	Lãvdnjajåkka	**224001006R**	**N2**		**12**
	Luos'tejohka	**224001023R**	**N2**		**12**
	Luos'tejåkka	**224002291R**	**N2**		**12**
Børselvvassdr	**Bis'sujåkka**	**225001061R**	**N2**		**12**
	Bis'sujåkka	**225002371R**	**N2**		**12**
	Bis'sujåkka	**225002541R**	**N2**		**12**
	Viek'sajåkka	**225002357R**	**N2**		**12**
	Månsjåkka	**225000987R**	**N2**		**16**[4]
	Bis'sujåkka	225000991R	N2		18
Tana			N2	?	?
Pasvikelva			N2	?	?
Vesterelvvassdr	**Syltefjordelva**	**237001837R**	**N2**	**(R-N2)**	**1**
	Syltefjordelva	**237001841R**	**N2**	**(R-N5)**	**9**
	Oardujav'ri **Stuorra Oar'do** **Syltefjordelva**	**237000912R**	**N2**	**(R-N7)**	**16**
	Rav'dul Syltefjordelva	237000896R	N2		18[2]
Sandfjordvassdr	**Sandfjordelva**	**238001744R**	**N2**	**(R-N2)**	**1**
	Sandfjordelva	**238000990R**	**N2**	**(R-N7)**	**16**
	Sandfjordelva	**238001219R**	**N2**	**(R-N7)**	**16**
Jardfjordvassdr	Baccavãjåkka	246000003R	N2	(R-N3)	2
Sudajåkka????	**Sudajåkka**	**247000176R**	**N2**	**(R-N9)**	**10**

[1] Large, mid-altitude, siliceous, very low alkalinity, clear
[2] Small-Medium, highland, siliceous, moderate alkalinity, organic (mixed)
[3] Large, mid-altitude, siliceous, moderate alkalinity, organic (mixed)
[4] Small-Medium, highland, siliceous, low alkalinity, organic