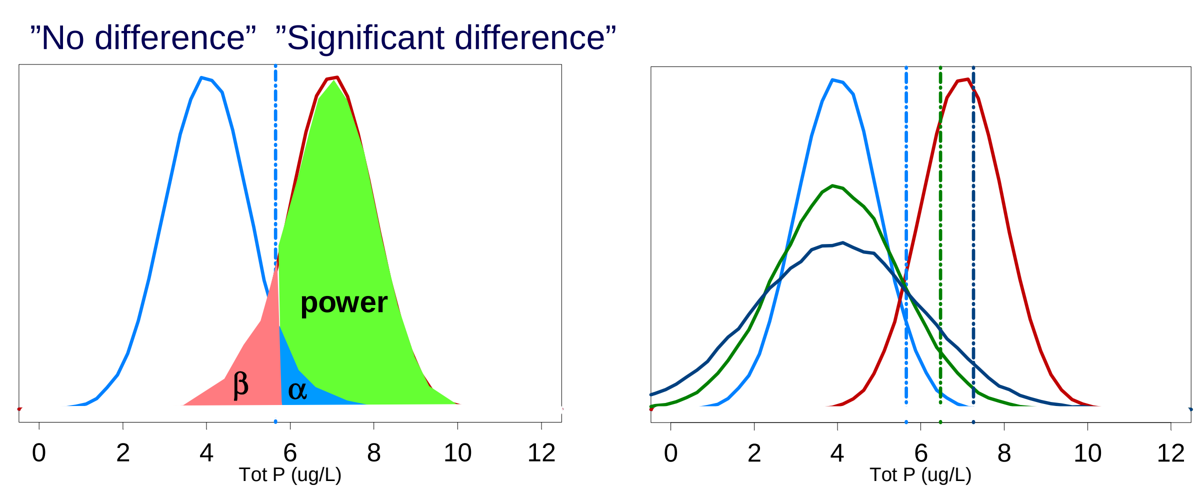
RAPPORT LNR 5003 - 2005

Proposal for Design of a Norwegian Monitoring Network for Reference Sites

Biological quality elements	Lakes	Rivers	Coastal waters
Phytoplankton			
Benthic algae			
Macrophytes			
Benthic fauna			
Fish			
Zooplankton	+		



Norsk institutt for vannforskning

RAPPORT

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Sammendrag

The present report is a proposal for a preliminary design of a monitoring programme for reference sites for all surface water categories compatible with the requirements in the EU Water Framework Directive. The proposal includes preliminary recommendations of number of sites, parameters, sampling frequency and monitoring intervals. The total number of sites proposed is approximately 400 lakes, 250 river sites and 250 coastal water sites distributed in different ecoregions and types. A tentative budget suggests annual costs for the initial 6-years' period of 140 mill. NOK, with 30, 20 and 90 mill. NOK for lakes, rivers and coastal waters respectively. For the consequtive monitoring periods, the annual costs decrease to ca. 28 mill. NOK, in which lakes, rivers and coastal waters require respectively 7.5, 5 and 15 mill. NOK. The costs can be further reduced by combining the reference network with ongoing and planned monitoring in Norway and in other Nordic countries.

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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Proposal for design of a Norwegian Monitoring Network for Reference Sites

Final report, 15th April 2005

Preface

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 work has been done for the Norwegian Directorate for Nature Management, on behalf of the Norwegian Directorates' group on Monitoring.

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Oslo, 15th April 2005

Anne Lyche Solheim

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Bakgrunn og målsetning

Rapporten er skrevet på oppdrag fra Direktoratet for Naturforvaltning på vegne av Direktoratsgruppen for Implementering av EUs Rammedirektiv for Vann, Overvåkingsgruppen.

EUs Rammedirektiv for Vann krever fastsettelse av økologisk status for alle vannforekomster i innsjøer, elver og kystvann. Økologiske status skal oppgis som avvik fra naturtilstand eller såkalt referansetilstand i hht. Vedlegg V i Direktivet. Det er derfor nødvendig å definere referansetilstanden med en grad av nøyaktighet som gir tilstrekkelig utsagnskraft i analysen av evt. avvik fra denne naturtilstanden. For å definere naturtilstanden med nødvendig nøyaktighet er det behov for å etablere et overvåkingsprogram som består av et nettverk av vannforekomster i referansetilstand. Disse vannforekomstene vil danne bunnlinjen i det langsiktige overvåkingsprogrammet som kreves opprettet i hht. Vedlegg V ("surveillance monitoring"). Et slikt referansenettverk må kunne gi grunnlag for å sette type-spesifikke referanseverdier og konfidensgrenser for alle elementene som er oppført i Vedlegg V.

Målsetningen med denne rapporten er å foreslå en struktur for et overvåkingsprogram for referanselokaliteter i innsjøer, elver og kystvann. Forslaget omfatter en foreløpig identifisering av lokaliteter, parametre, prøvetakingsfrekvens og overvåkingsintervaller.

Materiale og metoder

Arbeidet er basert på eksisterende overvåkingsdata fra norske vannforekomster i alle de tre vannkategoriene. Disse datasettene er dels analysert vha. forskjellige statistiske teknikker og dels vurdert av eksperter innen de ulike vannkategoriene. Rapporten er basert på dialog med oppdragsgiver underveis i prosessen, og skal brukes videre i dialog med andre nordiske land med tanke på eventuell samordning av lokaliteter av samme type i de forskjellige landene.

Generelle resultater og anbefalinger felles for alle vannkategoriene

Statistiske analyser

Kvantifisering av den naturlige variasjon innen en vannforekomst er nødvendig for å kunne påvise forskjell i økologisk status mellom vannforekomster, eller forandringer innen en vannforekomst. Denne kvantifiseringen er nødvendig for å kunne teste om forskjellen mellom to lokaliteter eller grupper av lokaliteter er signifikant i forhold til variasjonen innen hver gruppe. "Grupper" vil i denne sammenhengen representere typer av vannforekomster (f.eks. humus-fattige og kalk-rike innsjøer) innen avgrensede regioner (f.eks. lavlandet på Østlandet). Den naturlige variasjonen kan tilskrives ulike kilder: prøvetakingsvariasjon, romlig variasjon (mellom lokaliteter) og tidsmessig variasjon (innen én eller flere lokaliteter). Sannsynligheten for å påvise en reell forskjell mellom en påvirket lokalitet og en gruppe referanselokaliteter kan beregnes som statistisk utsagnskraft ("power"). Utsagnskraften til en statistisk test vil bl.a. øke med antall prøver, og vil reduseres med variasjonen innen gruppen av referanselokaliteter. Hvordan antall prøver fordeles i tid vs. rom har betydning for utsagnskraften, og kan ha ulik betydning for ulike biologiske elementer. Sannsynligheten for å påvise en tidsmessig trend innen en referanselokalitet kan på tilsvarende måte beregnes ved utsagnskraft. Dette krever imidlertid svært gode data, så enklere tester av tilstand "før vs. etter" kan være mer aktuelle.

Metodene som ligger til grunn for anbefalingene er en kombinasjon av ekspert-vurdering og statistisk beregning av naturlig variasjon for alle biologiske elementer, og beregning av utsagnskraft for forskjeller mellom lokaliteter eller endringer innen lokaliteter for enkelte elementer. Tilstrekkelig datagrunnlag for beregning av utsagnskraft er foreløpig tilgjengelig kun for enkelte biologiske elementer og enkelte vanntyper. Beregningene av utsagnskraft i denne rapporten bør derfor først og fremst betraktes som eksempler på hvordan framtidige overvåkingsdata kan brukes til å påvise forskjeller/trender innen referanselokaliteter.

Anbefalinger:

Ut fra de gjennomførte statistiske analyser og ekspertvurderinger gis følgende foreløpige generelle anbefalinger for overvåking av referanselokaliteter:

- Antall prøvetakingspunkter eller lokaliteter pr. vanntype og økoregion bør være minimum 10, men helst 20 for hver vanntype som er signifikant forskjellig for de enkelte biologiske elementene. For elementer med stor romlig variasjon, men liten tidsmessig variasjon (for eksempel bentisk flora og fauna) trengs flere lokaliteter enn for elementer med liten romlig variasjon (for eksempel planteplankton). For bentisk flora og fauna, samt for fisk foreslås minimum følgende antall lokaliteter (prøvetakingspunkter) for de tre vannkategoriene:

    - Innsjøer: ca. 300-400, fordelt på 5-6 økoregioner og 11 vanntyper pr. økoregion (ikke alle vanntyper er prioritert i de enkelte økoregioner)
    - Elver: ca. 250, fordelt på tilsvarende antall regioner og typer som innsjøer
    - Kystvann: ca. 250, fordelt på 4 økoregioner, 4 områder pr. økoregion, 4 vanntyper pr. område og 4 lokaliteter pr. vanntype innen hvert område og region

  For planteplankton i innsjøer og fysisk-kjemiske elementer i innsjøer og elver anbefales 50 lokaliteter fordelt på de 5 vannkjemiske grunntypene (svært lav, lav og moderat alkalitet, og høy el. lav humus)

- Prøvetakingsfrekvensen for de bentiske elementene, samt fisk bør minimum være 1 pr. år hvert 3. el. 6. år, mens for planteplankton og fysisk-kjemiske elementer må frekvensen være betydelig høyere for å fange opp sesongvariasjoner. For innsjøer anbefales minimum 5 prøver pr. år i vekstsesongen (mai-oktober), mens for kystvann anbefales minimum 15 prøver pr. år i vekstsesongen (mars-oktober)

- Alle de biologiske elementene som er gitt i Vedlegg V i Direktivet bør inkluderes i overvåkingen, med unntak av planteplankton i elver og bentiske alger i innsjøer. I tillegg anbefales dyreplankton i innsjøer inkludert, da dette elementet har stor indikatorverdi og det finnes mye overvåkingsdata og kompetanse på dette i Norge.

De tre typene variasjon (prøvetaking, romlig og tidsmessig) kan bli bedre karakterisert ved henholdsvis flere parallelle prøver per lokalitet, flere lokaliteter per region, og hyppigere prøvetaking per lokalitet. Selv om det er ønskelig å dekke alle tre typene variasjon, må overvåkingsdesignet nødvendigvis være et kompromiss mellom disse ønskene. For å kunne kvantifisere både romlig og tidsmessig variasjon anbefaler vi et 2-fase design med kombinasjon av intensiv og ekstensiv overvåking.

- Fase 1: den første seks-års perioden med høyere prøvetakingsfrekvens og 20 lokaliteter pr. vanntype for alle referanselokaliteter (for å kvantifisere romlig og tidsmessig variasjon).
- Fase 2: etterfølgende seks-års perioder med intensiv overvåking for noen få utvalgte lokaliteter (3-4 per vanntype og region), som i fase 1, og ekstensiv overvåking med minimalt design for det store flertall av lokaliteter (som angitt ovenfor). Dette gir nødvendig utsagnskraft i trendanalyser, samt påvisning av større regionale endringer.

Budsjett

Et tentativt budsjett antyder at kostnadene for første fase vil være ca. 140 mill. NOK pr. år i den første 6-års-perioden, fordelt med ca. 35% til ferskvann og 65% til marine vannforekomster. I neste fase, dvs. de påfølgende 6-årsperiodene synker kostnadene til ca. 28 mill. NOK pr. år med ca. 45/55 fordeling mellom ferskvann og marint.

Innsjøer

De nasjonale overvåkingsprogrammene innen eutrofiering (EUREGI, Oredalen & Faafeng 2002) og forsuring (Skjelkvåle et al. 1995) ble brukt som basis for forslaget til design av overvåkingsprogrammet for referanselokaliteter for innsjøer. Fra datasettene fra disse programmene ble det plukket ut hhv. 504, 192, 39 og 154 antatt upåvirkede innsjøer for statistiske analyser av naturlig variasjon i fosfor, planteplankton, litorale krepsdyr og fisk. Analyser av romlig variasjon, dvs. variasjon mellom lokaliteter innen samme vanntype, ble brukt for å gi anbefaling av antall lokaliteter pr. vanntype. Analyser av tidsvariasjon var hovedsakelig basert på datamateriale fra Atnsjøen, både sesongvariasjon innen enkeltår, samt år-til-år variasjon for de enkelte biologiske elementene. Resultatene fra disse analysene ble brukt til å anslå prøvetakingsfrekvens innen et år og overvåkingsintervall, dvs. om lokalitetene bør overvåkes hvert år, hvert annet år, hvert tredje år etc.

51 innsjøtyper anbefales prioritert. Disse består av 11 basistyper mht. vannkjemi (alkalitet og humus) og høyderegioner (lavland, skog, fjell) i 6 økoregioner (Øst, Sør, Vest, Midt, Nord-indre og Nord-ytre) som angitt i Lyche-Solheim et al. 2003 og Lyche-Solheim og Schartau 2004. Disse innsjøtypene omfatter alle interkalibreringstypene, samt andre viktige sær-norske innsjøtyper, som for eksempel svært kalkfattige klarvannssjøer som er sårbare for forsuring. For hver av disse vanntypene bør utvalget av referanselokaliteter omfatte både grunne og dype innsjøer, da disse forventes å ha forskjellige respons på klimaendringer og på andre belastninger.

Analysen av romlig variasjon innen enkelte vanntyper og enkelte elementer antyder at det nye referansenettverket bør ha minimum 10, og helst 20 lokaliteter pr. vanntype. Dette innebærer et totalt antall lokaliteter på minimum 510 og helst 1020 innsjøer (basert på 51 innsjøtyper). Aktuelle innsjøer som kan inngå i dette referansenettverket er foreløpig identifisert ut fra et tidligere utvalg av 500 potensielle referansesjøer (Lyche-Solheim et al. 2003). Etter at disse ble sjekket i forhold til resultatene av karakteriseringsprosjektene (Stalsberg, NVE pers.comm.), fant vi at kun 126 av disse ble vurdert å være upåvirkede innsjøer ("clearly not at risk"). Dette utvalget må derfor suppleres med et stort antall lokaliteter. Da de utvalgte 126 innsjøene bare utgjør ca. 4% av det totale antallet upåvirkede innsjøer i hht. karakteriseringsprosjektene (Stalsberg, NVE pers. comm.), bør det være mulig å finne et tilstrekkelig antall referanselokaliteter for mange av de prioriterte vanntypene. Dette kan gjøres så snart resultatene fra karakteringsprosjektene blir gjort tilgjengelige.

Fordelingen av de 126 utvalgte innsjøene på de 51 vanntypene viser at det store flertallet tilhører svært kalkfattige eller kalkfattige innsjøer. Den geografiske fordelingen av disse viser at det er svært få svært kalkfattige referansesjøer på Sørlandet, pga. forsuringen. For moderat kalkrike innsjøer ble det kun funnet totalt 14 i det eksisterende utvalget (ca. 10%), og de fleste av disse er i Nord-Norge. Den største utfordringen blir derfor å finne et tilstrekkelig antall moderat kalkrike referansesjøer i Sør og Midt-Norge, samt svært kalkfattige referansesjøer på Sørlandet. For disse innsjøtypene kan andre metoder (modeller og paleoøkologiske analyser av sedimentkjerner) benyttes for å estimere referansetilstanden.

I hht. kravene i Rammedirektivet skal følgende biologiske elementer inngå i referanseovervåkingen: planteplankton, fastsittende alger, makrofytter (vannplanter), bunnfauna (litoral) og fisk. Da det verken finnes data eller kjente sammenhenger mellom fastsittende alger i innsjøer og ulike påvirkninger anbefaler vi at dette elementet ikke prioriteres i dette nettverket. Derimot anbefaler vi at dyreplankton inkluderes, selv om det ikke er et krav i Rammedirektivet. Dyreplankton har stor indikatorverdi både i forhold til påvirkninger og i forhold til fisk, samt at dyreplankton kan forklare mye av variasjonen i dose-respons-kurver for fosfor og planteplankton. Norge har også lange tradisjoner, mye data og mye kompetanse på dyreplankton. For profundal bunnfauna anbefales dette kun prioritert i vanntyper som er utsatt for eutrofiering, dvs. kalkfattige og moderat kalkrike innsjøer i lavlandet. Norge har begrenset kompetanse og lite data på dette elementet (Univ. i Bergen).

Av fysisk-kjemiske støtteelementer er følgende parametre aktuelle: Tot-P, PO4, Tot-N, NO3, siktedyp, farge, turbiditet, temperatur, oksygen (i bunnvann), TOC, pH, Ca og ANC, samt evt. labilt aluminium (sistnevnte kun i svært kalkfattige og kalkfattige vanntyper). De viktigste hydromorfologiske støttelementene er vannstandsvariasjoner og tidspunkt og varighet for isdekke.

Analysene av tidsvariasjon viser at følgende prøvetakingsfrekvens er ønskelig pr. år:

- Planteplankton og vannkjemiske parametre — minst 5 og helst 10
- Vannplanter — 1 gang i perioden juli-september
- Dyreplankton — minst 3 (juni, august, oktober)
- Litoral bunnfauna — minst 1, helt 2 (mai og oktober)
- Fisk — 1 gang i september

Mht. overvåkingsintervall, bør planteplankton og vannkjemi tas hvert år i første 6 års periode (optimalt design) og deretter hvert 3. år (minimalt design), mens de andre biologiske elementene bør tas hvert 2. år i første 6 års periode og deretter ett år for hver 6 års periode. For å få tilstrekkelig utsagnskraft i trendanalyser anbefales at et lite utvalg lokaliteter (for eksempel 3 pr. vanntype) følger optimalt design hele tiden.

Det er ikke nødvendig å overvåke alle elementene i alle lokalitetene, da de ulike elementene har forskjellig romlig variasjon. For eksempel viser planteplankton forskjeller mellom bare 4 vanntyper, mens fisk viser forskjeller mellom 42 vanntyper. Dette skyldes at planteplankton ikke responderer på høyde over havet el. på forskjellige økoregioner, men kun på vannkjemiske forhold (alkalitet og humus), mens fisk responderer på alle disse faktorene. Det totale antall lokaliteter som må overvåkes for de forskjellige elementene er:

Element	Minimalt design	Optimalt design
Planteplankton	40	80
Dyreplankton	310	620
Makrofytter	310	620
Bunnfauna (litoral)	430	860
Fisk	390	780

Tentativt budsjett for overvåking av referanselokaliteter for innsjøer er ca. 30 mill. NOK pr. år i den første 6 års perioden, og deretter ca. 7.5 mill. NOK pr. år i de påfølgende 6-årsperiodene. Dette gjelder dersom man følger anbefalingen om å la et lite antall lokaliteter overvåkes med optimalt design også etter den første 6-årsperioden.

Synergier med andre eksisterende og planlagte overvåkingsprogrammer i Norge og Norden kan redusere disse kostnadene ytterligere. Aktuelle programmer som bør vurderes nærmere i denne sammenheng er: Den samordnede innsjøundersøkelsen for forsuring og miljøgifter, NVEs stasjonsnett for vannstandsmålinger, samt tilsvarende programmer for overvåking av referanselokaliteter som er under planlegging i andre nordiske land.

Elver

Overvåking av referansetilstand for hydromorfologiske, fysisk-kjemiske og biologiske forhold i rennende vann bør i utgangspunktet dekke alle vanlige elvetyper i Norge. For å få best mulig usagnskraft for vurdering av økologisk status anbefales å inkludere relativt mange lokaliteter for et utvalg elvetyper framfor å inkludere alle eksisterende elvetyper med et fåtall lokaliteter av hver type. Prioritet bør gis til 1) elvetyper inkludert i interkalibreringsarbeidet, 2) andre norske elvetyper som anses som spesielt sårbare i forhold til eutrofiering (elvetyper i lavlandet) og forsuring (svært kalkfattige og kalkfattige elvetyper) samt 3) andre vanlige elvetyper som kan være mer sjeldne i Europa forøvrig.

Kunnskap om naturlig variasjon i tid og rom er generelt mangelfull når det biologi i rennende vann. Det eksisterer få, om noen, datasett som er egnet for å vurdere hvor mange lokaliteter av hver type som bør inkluderes i overvåkingsnettverket for å oppnå ønsket utsagnskraft. Basert på generelle statistiske betraktninger anbefaler vi at det i utgangspunktet inkluderes et relativt stort antall lokaliteter av hver type; optimalt 20 lokaliteter med 10 lokaliteter som et minimum. Ved etablering av referansenettverket bør det sikres at et minimum antall vassdrag (2-4) i hver økoregion, der de aktuelle elvetypene er representert, inkluderes. For hvert av vassdragene etableres anslagsvis 5 lokaliteter av hver representerte type. Prioritet bør gis til vassdrag som dekker flere elvetyper. Videre anbefales det at dette utvalget overvåkes intensivt (optimal overvåkingsfrekvens) i en 6 års periode. En slik intensiv overvåking vil kunne sikre et godt datagrunnlag for å kunne optimalisere overvåkingen i påfølgende perioder, for eksempel gjennom et redusert lokalitetsutvalg og mer differensiert overvåking. Etter den første perioden vil de fleste lokalitetene kunne følges mer sjeldent (minimum overvåkingsfrekvens). Et mindre antall lokaliteter (2-4) av hver type bør imidlertid overvåkes intensivt også i de følgende overvåkingsperiodene. På denne måten vil det kunne tas hensyn til både romlig variasjon og variasjon over tid (for eksempel som skyldes klimaendringer). Alternative budsjett for optimalt overvåkingsdesign, for den første 6 års perioden og minimum overvåkingsdesign for påfølgende overvåkingsperioder er presentert.

Av kvalitetselementene som nevnes i Vedlegg V, seksjon 1.2.1 i Rammedirektivet for vann vurderer vi kun planteplankton som lite relevant å inkludere i elve-overvåkingen. Denne vurderingen er basert på en generell mangel på egnet habitat (elvestrekninger med lav strømhastighet) for planteplankton i norske vassdrag. De øvrige biologiske kvalitetselementene (påvekstalger, makrovegetasjon, makroinvertebrater og fisk) bør alle inkluderes i overvåking av referansestasjoner i rennende vann. Dette er nødvendig for at nettverket skal kunne være egnet for å vurdere effekter av ulike påvirkningstyper (eutrofiering, forsuring, hydromorfologiske endringer). I tillegg foreslår vi at alle typifiseringsparametrene samt andre fysisk-kjemiske og hydrologiske (vannføring, islegging/-gang) støtteparametere overvåkes relativt hyppig mens hydromorfologiske støtteparametere undersøkes en gang per overvåkingsperiode.

Lyche Solheim et al. (2003) presenterte 50 vassdrag som utgangspunkt for utvelgelse av referanselokaliteter. Disse vassdragene er sjekket mot resultatet fra Karakteriseringsprosjektene (status per januar 2005). I denne prosessen ble alle kalkede og forsurede vassdrag i Sør-Norge fjernet og likeledes vassdrag / deler av vassdrag som er indikert som at risk eller potentially at risk i hht. Karakteriseringen. Resultatet er et utvalg på 30 vassdrag der minst et vannobjekt er vurdert som en potensiell referanselokalitet. De fleste vassdragene er imidlertid representert med flere lokaliteter og typer, slik at utvalget består av 90 potensielle referanselokaliteter og 32 elvetyper. Flest lokaliteter er registrert for klare, kalkfattige elvetyper i alle klimaregioner. De fleste utvalgte referanselokalitetene ligger i Midt-Norge og indre deler av Nord-Norge. Ingen referanselokaliteter ble funnet for Sørlandet og sørlige deler av Vestlandet pga. forsuring. Ytre deler av Nord-Norge har antagelig også få referanselokaliteter pga. vassdragsreguleringer. Utvalget av alle aktuelle elvetyper er imidlertid for lavt.

Det videre arbeidet med etablering av referansenettverk for elve-overvåking må utvalget av aktuelle referanselokaliteter økes. Resultatene fra Karakteriseringsprosjektene er helt avgjørende for dette arbeidet men det er også nødvendig å sjekke elvetype og økologisk status for potensielle referanselokaliteter vha. overvåkingsdata og lokal kunnskap. Dette gjelder spesielt for utvalget av lokaliteter i forsurede vassdrag. Etablering av konkrete overvåkingslokaliteter innenfor de utvalgte referanseområdene gjenstår og må gjøres med basis i erfaringer fra eksisterende undersøkelser og lokal kunnskap. Brepåvirkede elvetyper er så langt ikke prioritert i etablering av referansenettverket. Dette er elvetyper som er vurdert å være spesielt sårbare overfor klimaendringer og inkludering av brepåvirkede elvetyper bør derfor vurderes.

Kvantifisering av de ulike komponentene for naturlig variasjon (i tid og rom) vil kunne bidra til en optimalisering av overvåkingsdesignet. Det finnes noen biologiske datasett (bunndyr-datasettet i VannInfo og tidsserier for påvekstalger, bunndyr og fisk fra Atnavassdraget) som er egnet for dette formålet.

Kystvann

Rammedirektivet for vann (VRD) forutsetter at det skal opprettes et referansenettverk for alle nasjoners kystvann. Kystvann er et forvaltningsmessig begrep og omfatter alle marine vannforekomster som strekker seg ut til 1 nautisk mil utenfor grunnlinjen. Grunnlinjen er en linje som vanligvis trekkes mellom de ytterste øyene langs vår kyst. Flere vannforekomster danner igjen en vanntype og innen hver vanntype skal en referansetilstand av økologisk status fastsettes. Referansetilstanden skal være uberørt/ikke menneskepåvirket og et grunnlag i vurderingen av økologisk status av de andre vannforekomstene i denne vanntypen. Økologisk status skal være basert på biologiske, fysiske-kjemiske og hydromorfologiske forhold og skal klassifiseres i 5 kategorier; høy, god, moderat, dårlig og svært dårlig. Alle referansestasjoner må være innen kategorien ”høy”.

Typifiseringen av norske vannforekomster er allerede utført og kystvannet langs norskekysten er inndelt i totalt 23 forskjellige vanntyper (Moy et al. 2003). De viktigste faktorene som typologien er basert på er; eksponeringsgrad, saltholdighet, tidevann, substrattyper, samt 4 biogeografiske økoregioner. Innen disse fire regionene er det da foreslått fra 5 til 7 forskjellige vanntyper.

Ifølge VRD skal den type-spesifikke referansetilstanden beskrives for hvert av de biologiske kvalitetselementene (planteplankton, bentiske alger og - evertebrater) som inngår i VRD. For hvert kvalitetselement skal det kunne settes referanseverdier med et konfidensintervall som avspeiler den naturlig variasjon. For å kunne realisere dette, er det nødvendig å opprette et overvåkingsprogram for referanselokaliteter med tilstrekkelig antall lokaliteter pr. vanntype til å kunne kvantifisere den naturlige variasjonen innen hver vanntype og økoregion.

De ulike kvalitetselementene som inngår i VRD stiller forskjellige krav til sampling-design ettersom de har forskjellig variasjon i rom og tid. Variasjonen i sammensetning og biomasse av planteplankton varierer mye over tid, for eksempel fra en måned til neste, mens flerårige fastsittende alger varierer lite innen samme periode. De vil derfor kreve ulik innsamlingsstrategi for å kunne fastsette variasjonen. Det er derfor valgt å foreta 20 innsamlinger av planteplankton pr. år for å kunne dekke årsvariasjonen, mens det for bentiske alger er valgt å foreta én innsamling i året. For å dekke den romlige variasjonen er det valgt et minimum av 4 stasjoner innen hver vanntype for hvert av de biologiske kvalitetselementene. For hydrografi og hydromorfologiske undersøkelser er det også valgt 4 stasjoner innen hver vanntype, men på grunn av den betydelige variasjonen over tid, er det som for planteplankton valgt å samle inn prøver 22 ganger i året.

I utvelgelsen av referanseområder er det også tatt hensyn til andre relevante programmer som;

- ”Nasjonal overvåking av marint biologisk mangfold i kystsonen”(Nygaard et al. 2004),
- ”European marine biodiversity reseach sites” (BIOMARE-programmet;Warwick et al. 2003)
- ”Rådgivende utvalg. Råd til utforming av marin verneplan for marine beskyttede områder i Norge” (Skjoldal et al. 2003)

Referanseområdene er valgt ut slik at innsamling av data og resultatutveksling kan koordineres og optimaliseres. Andre undersøkelser som omfatter kvalitetselement som faller innenfor rammene for dette referansenettverket er også inkludert hvor det var mulig.

De områdene som er valgt ut som potensielle referanseområder omfatter de fleste vanntyper fra ytre eksponert kyst til ferskvannspåvirkete, beskyttete poller innen hvert område. Det er foreslått å utelate vanntypene ”strømrike sund” og ”beskyttede områder med lang oppholdstid” fra et slikt referansenettverk innen VRD ettersom lokaliteter innen denne vanntypen er unike innen sitt lokale område og at det derfor ikke kan settes en referanseverdi for en slik vanntype på generelt grunnlag. Vanntypene ”beskyttet polyhaline” og ”beskyttet fjord” er også slått sammen, da de i utgangspunktet i stor grad overlapper med hverandre. Basert på disse reduksjonene vil da 3-4 vanntyper bli undersøkt i 4-5 områder innen hver av de 4 økoregionene. For hver vanntype vil 4 stasjoner (vannforekomster) bli undersøkt, for å dekke den romlig variasjonen og for å kunne gi hvert enkelt biologisk kvalitetselement et konfidensintervall som kan beskrive den naturlige variasjonen innen hver vanntype. Dette er et minimumsopplegg, som også gjør det mulig å vurdere videre behov for justering av prøvetakingsdesign og videre oppdeling av de foreslåtte vanntypene innenfor dette programmet.

I den første kartleggende fasen vil behovet for stasjoner og prøvetakingsfrekvens være betydelig større enn når en går over i en operativ fase. Minimumsrammen for den kartleggende fasen vil være omtrent på 93 mill. NOK pr. år, mens den i en operativ fase vil ligge på omtrent 23 mill. NOK pr. år.

Summary

Title: Proposal for Design of a Norwegian Monitoring Network for Reference Sites
Year: 2005
Author: Anne Lyche Solheim, Ann Kristin Schartau, Jannicke Moe, Ola Diserud, Frithjof Moy, Frode Olsgard, Are Pedersen
Source: Norwegian Institute for Water Research, ISBN No.: ISBN 82-577-4701-7

The objective of this report has been to propose a design for a new WFD-compatible Norwegian monitoring programme for reference sites in lakes, rivers and coastal waters. The proposal includes preliminary recommendations of number of sites, parameters, sampling frequency and monitoring intervals, based on a combination of expert judgement and statistical analyses on restricted existing data from reference sites. A first selection of sites is also proposed for all the water categories. The design proposed will be suitable to define the type-specific natural variation in different elements in the different water categories, and thus will allow the quantification of the reference conditions for all prioritized types of water bodies. Based on this baseline, the ecological status of most impacted sites can be defined as deviations from reference conditions.

The design proposed also recommends a combination of extensive and intensive monitoring, where the first 6 year period should be intensive, in terms of a high number of sites and high sampling frequency to quantify spatial and temporal variation for all elements and types. For the consecutive 6-year periods, the number of sites and sampling frequency can be reduced, but keeping a few sites per type with high sampling frequency to obtain sufficient power in long-term trend analyses. The total number of sites proposed is approximately 400 lakes, 250 river sites and 250 coastal water sites distributed on different ecoregions and types within each ecoregion. For types where there are none or very few existing sites currently in reference conditions, other methods are recommended for the assessment of reference conditions, such as models or paleo-ecological analyses of sediment cores. The selection of sites should be based upon the risk assessment done in the characterisation of water bodies, to ensure that all selected sites have been designated as being clearly not at risk of failing the WFD objective.

A tentative budget is proposed for all the water categories for the initial and for the consequtive 6-year monitoring periods. This suggests that the total annual costs for the initial 6-years period are 140 mill. NOK, with 30, 20 and 90 mill. NOK for lakes, rivers and coastal waters respectively. For the consequtive monitoring periods, the annual costs decrease to approximately 28 mill. NOK, in which lakes, rivers and coastal waters require respectively 7.5, 5 and 15 mill. NOK. The costs can be further reduced by combining/merging the reference network with ongoing and planned monitoring programmes in Norway and in other Nordic countries.

1. Introduction

1.1 Background

An important part of the implementation of the EU Water Framework Directive is to assess the reference conditions for all types of water bodies, as the baseline for assessment of ecological status in all water bodies. Ecological status is defined as deviations from reference conditions. This applies to all categories of surface waters (lakes, rivers and coastal waters). In order to establish this baseline, a network of reference sites is needed. A reference site is defined in this context as a water body in high ecological status, which is equivalent to reference conditions. The monitoring of reference sites should provide the numerical basis for setting type-specific reference values and confidence intervals for all elements listed in Vedlegg V of the Directive.

1.2 Objective

The objective of this report is to propose a design for a Norwegian Reference Sites Monitoring Network for rivers, lakes and coastal waters. The proposal includes a preliminary identification of sites, parameters, sampling frequencies and monitoring intervals. The monitoring network should provide sufficient data to enable quantification of the baseline for assessment of ecological status. This means to establish type-specific reference values with sufficient precision, to enable reliable quantification the natural mean values as well as natural spatial and temporal variation for all biological and supporting physico-chemical and hydromorphological elements required in the Vedlegg V of the Directive.

1.3 Work process

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

- to compile existing biological and physico-chemical data from as many reference sites as possible for each surface water category
- to organize 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 with experts of the different water categories
- to perform statistical analyses of the data sets in order to recommend the optimal and minimal number of sites, elements and frequencies (done partly prior to, partly during, and partly after the workshop)
- to draft a report presenting the proposal for the design of the Reference Network

The first draft report has been revised according to comments from the Norwegian national authorities responsible for WFD monitoring.

This present final report will be used as a basis for further collaboration among 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. Common considerations for all surface water categories

2.1 Statistical considerations

The aim of the statistical analyses and considerations is to provide the basis for recommendations on the number of sites per type, sampling frequency per year, and the number of years of observation required to quantify the natural variation within and between reference sites of the same type. Quantification of natural variation within and/or between reference sites is necessary for performing statistical power analyses, i.e. assessing the probability for detecting a significant deviation from the natural variation. The future monitoring of reference sites should provide the baseline for detecting:

1) Differences between reference sites (high class) and lower classes of ecological status, since high status sites represent the baseline for the new classification system

2) Temporal trends within sites:

i) trends within single reference sites, due to local impacts: these sites may no longer qualify as reference sites (and may require measures)

ii) common trends within several reference sites, due to regional or global impacts (such as climate change): this may change the restoration target, and thus lead to the need for adjustments of the programme of measures to restore impacted sites according to the new baseline (**Figure 1**).

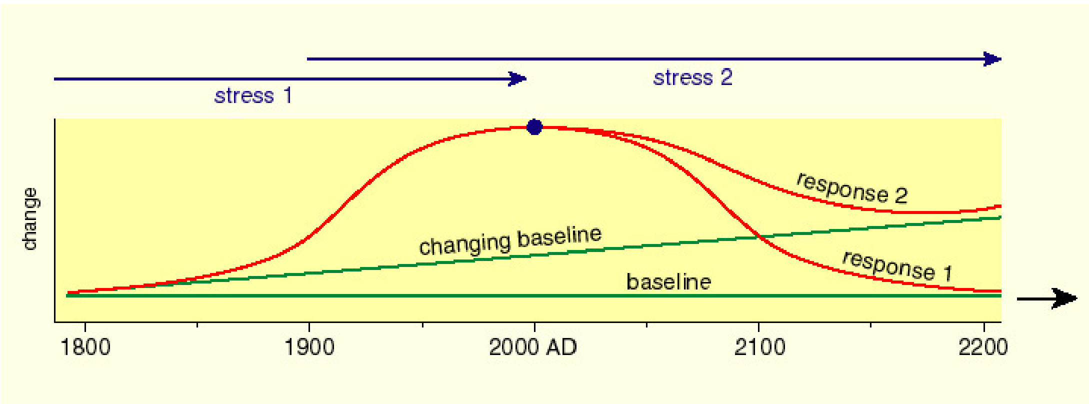

Figure 1. The effect of a changing baseline (reference conditions) on the programme of measures (response), from R. Johnson and R. Battarbee, Eurolimpacs EU-project description.

2.1.1 Natural variation

In order to detect deviations from reference conditions for any site, we must first of all obtain sufficient knowledge on the natural variation. What is the expected precision of an estimate? How large is the spatial variance? How large fluctuations can be expected from year to year? Only when these questions are answered, the specifications can be given on monitoring design suitable to detect deviations beyond natural fluctuations, possibly caused by human impact on habitat quality.

The observed variance in a data set, consisting of all samples, can be regarded as the sum of several variance components. If we have a sufficient number of samples to estimate each component, we can identify the contribution of each component to the total variance. It also enables us to increase the power of the test by removing "irrelevant" components; irrelevant regarding the actual comparison of reference sites and the possibly impacted site.

The first component is the **sampling variance**. This component is caused by randomness in the sampling process, and the effect will decrease with increasing sample size or sample number. The precision of all parameter estimates will be affected, so before we can isolate the other variance components, we must quantify the sampling variance. This could be done analytically, but is usually done by several replicate samples (from the same site at the same time), with a standardized sampling design. For a specified precision, we can then calculate the required number of parallels needed. If information on sampling variance is missing, the estimates for spatial and temporal variances will be confounded with sampling uncertainty.

The next variance component is the **spatial variance**. The sites can be sorted into different types depending on geographical region and climatic conditions, and typology factors such as water chemistry, altitude, size or depth. If we have a sufficient number of reference sites from each type, we can estimate the within-type and between-type variances. The within-type variances will be applied when testing if a possibly impacted site is significantly different from reference sites of the same type. The between-type variance describes the effect that geographical region, climate or basic water chemistry have on the parameters. If the number of reference sites is sub-optimal, we must reduce the number of types by pooling some related types together in order to obtain a sufficient number of sites in each type. This will increase the within-type variance and thereby reduce the power of the tests. If the within-type variance thus becomes too large, it may be necessary to exclude a whole water body type, or to split it into different types along other typology factor axes to reduce the variation to an acceptable level.

As an illustration of how different variance components can be quantified, we decomposed the spatial variance into within-type and between-types. A simplified assumption would be that the within-type variance is constant, i.e. equal for all types, and that the different variance components are independent. We also assume that the means from each type are "random observations from some distribution". Let:

(1) $$s_{btm}^2 = s_{bt}^2 + \frac{1}{m}\sum_{i=1}^{m}\frac{s_{bs_i}^2}{n_i}$$

where s^2_{btm} is the variance in mean values between types, s^2_{bt} the actual variance between the types, the last term express the weighted effect of the "between sites variance" within each type (m = number of sites, s^2_{bsi} = variance between sites in type i, n_i= number of sites in type i). With words; the variance between the calculated means of the types represent a sum of the variance between the "real" means and the weighted standard errors of the calculated means.

The third variance component is the **temporal variance**. Temporal dynamics can be caused by seasonal variation, year-to-year fluctuations caused by varying environmental conditions, and trends or cyclic dynamics. For the reference sites, we assume that there are no trends or cyclic dynamics (trend in reference sites will be dealt with separately). The seasonal variation is usually considered a nuisance parameter, where the effect can be reduced by increasing the number of samples through the season. The less frequently we monitor the sites, the longer it will take to detect any actual change.

The year-to-year variation can be modelled in two ways. First, we can assume that the abundances of a biological element from the same site at different years are more or less independent. This can be an acceptable assumption for short-lived species (phytoplankton, zooplankton) that are very sensitive to fluctuating environmental conditions. The abundances tend to fluctuate around some mean level (i.e. the carrying capacity), so we can estimate the variance directly from the yearly abundances.

Secondly, for biological elements with average life span of more than one year (some macrophytes, fish), we must necessarily expect dependence between abundances at the same site at consecutive years. We can then model the population dynamics as a diffusion process (e.g. Lande et al. 2003) with infinitesimal mean $m(x)$ (expected change into the next year; often modelled as a classical deterministic growth equation) as follows:

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

where x is the abundance, 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. The infinitesimal variance $v(x)$ (the stochastic term in the population dynamics) can be written on the form:

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

where σ^2_e 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. Let x_i be the abundance at time i, i=1, .., n, and t the time between consequtive observations (t=1 if yearly). A first order approximation to σ^2_e is then:

(2) $$\sigma_e^2 \approx \frac{1}{t} \frac{E\left[\left(x_i - x_{i+1}\right)^2\right]}{E\left[x_i^2\right]}$$

The environmental variance can then be estimated by replacing the expectations by the corresponding means. The estimated variance of the process is then $\hat{\sigma}_e^2 \cdot \bar{x}^2$.

The crucial question is then to which degree we can assume synchronicity in population dynamics, i.e. can we transfer knowledge on temporal variation from one site, or spatial type, to another? Or do we have to estimate the temporal variance separately for all types? In the case of perfect synchronicity, we know that if a population decrease at one site, the same species will have roughly the same decrease at another site. If we have no synchronicity at all, knowing the dynamics at one site gives no clue on the dynamics at other sites, i.e. all sites develop independently.

After all the required variance components are estimated with a satisfactory precision, we can decide how far from the mean reference conditions the parameter must be before we can claim that there has been a significant change and that the site must be reclassified. This will in part be a political decision, depending on how precautious we want to be, and in part depend on the magnitude of the natural variation. When this decision is made, recommendations on the number of samples, or sampling frequency, required to obtain a given test power can be given.

2.1.2 Test principles

Two main types of tests will be described: (1) a test for detecting a difference between a possibly impacted site and one or more reference sites, and (2) a test for detecting a temporal trend within one or more reference sites.

Figure 2 A and B illustrates the relationship between natural variation and statistical power: What is the probability that a statistical test will detect a certain difference between an impacted site and the reference sites? In both panels, the left distribution illustrates the natural variation of the reference sites (including some spatial variance components and the sampling variance), whereas the right distribution describes the sampling variance of the possibly impacted site. Figure 2A illustrates the concepts of statistical significance and statistical power. The selected significance level (typically α = 5%) determines the critical value of the parameter (vertical line in plot). The significance level is the probability for "false alarm" (falsely 'detecting' a difference), and corresponds to the proportion of reference sites with Tot P values above the critical value. The power is the probability for correctly detecting a difference between the reference sites and the impacted site, and corresponds to the proportion of impacted sites with Tot P values above the critical value. The selected significance level will directly influence the power of the test, so if we consider the 'cost' of not detecting a true difference to be greater than the 'cost' of giving a false alarm, the significance level should be increased to e.g. 10%. A tentative precautionary monitoring design could be to operate with a relatively high significance level, and when the test claims that there has been a change, the sampling effort should be increased in order to check if the claimed change is true or not.

Figure 2B illustrates how natural variation within/among reference sites affects the probability for detecting differences. A higher variation in total P among reference sites will move the critical line closer to the centre of the impacted-site distribution. This will reduce the proportion of total P samples from the impacted site that are above the critical line, which means a reduced probability for detecting a difference between the impacted site and the reference sites.

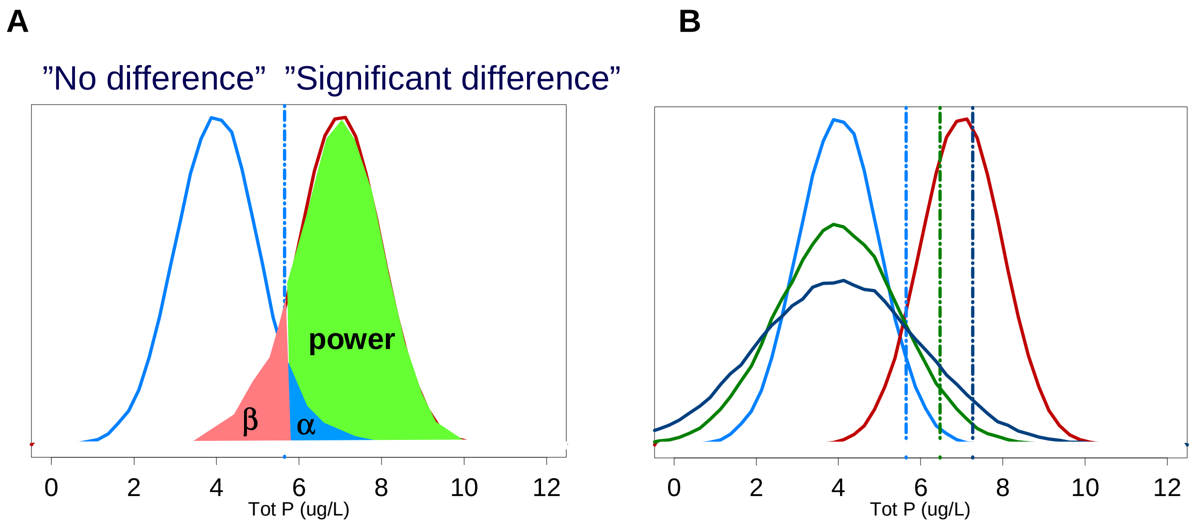

Figure 2. (**A**) Calculation of power. The blue and red curves represent distributions of total P values from reference sites and the (possibly) impacted site respectively. The selected significance level (α, the probability for "false alarm") determines the critical value (vertical line), which in turn determines β (the probability for "missing alarm"). The power is calculated as the proportion of samples from the impacted site that is above the critical value, which represents the probability for detecting a difference between the impacted site and the reference sites. (**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 of the test. In this case, doubling the standard deviation for the left (reference sites) distribution, while keeping the standard deviation of the right (impact site) distribution fixed, reduces the power from 91% to 39%.

The test power also increases with the number of sites, as well as with the magnitude of the difference to be detected, as illustrated in **Figure 3**. For other situations, with other distributions and levels of variance, the picture may look differently, but the general tendencies will be the same. By convention, a statistical power above 80% is desired.

We may want to compare a certain reference site against other reference sites, to test whether its ecological status is still "high". The difference we need to detect ("high" vs. "good" status or worse) is likely to be smaller than when testing an impacted site ("high" vs. "moderate" or worse). This means that we will require even lower variance, or more samples, in order to obtain the same statistical power.

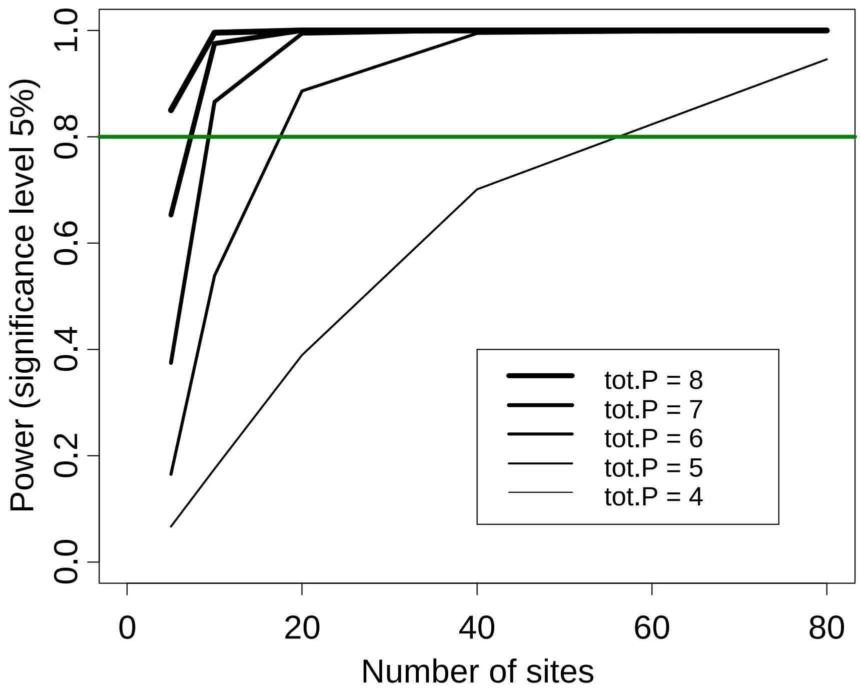

Figure 3. Illustration of statistical power analyses; the probability for detecting a difference in total P from 2.8 µg/L (mean for reference sites) to 4 - 8 µg/L (when the standard deviations are 1.0 for both distributions). Significance level is here chosen to be 5%. The test power increases with number of samples and with the difference to be detected. Horizintal line is the minimum power conventionally desired.

Estimating **temporal trends** in biological elements is a common goal of biologists and managers and gives an indication of changes in status within the different areas monitored. For a reference monitoring network, it is desirable to distinguish between local trends within single sites (possibly due to local impact) and regional trends within a type of sites (caused by e.g. climate change). Trends are typically inferred from data on abundance, number of species or diversity made on sampling sites 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 programme will detect a trend in sample data when the trend is occurring, despite the "noise" in the data, represents its statistical power. Consequences of ignoring statistical power include insufficient collection of data to enable reliable inferences about trends, or collection of data in excess of what is needed.

Estimates of statistical power for detecting temporal trends depend on

- the number of sites monitored,
- the number of replicates per site,
- the natural variation within sites (standard deviation),
- the duration of the monitoring,
- the sampling frequency and interval of monitoring,
- the magnitude and nature of ongoing trends in biological elements (eg. linear or exponential),
- variation in trends between sites within the same type,
- the significance level associated with trend detection (α-level),

Figure 4 illustrates how a trend in a mean value for references sites affects the probability for detecting a difference between the reference sites and an impacted site: here an increase in total P for reference sites reduces the statistical power. If this trend is due to local impact, the affected reference sites may have to be excluded as reference sites in order to retain the general baseline value for reference sites (and measures should be taken). However, if there is a large-scale trend affecting most reference sites, it may be necessary to redefine the boundary between the ecological status classes.

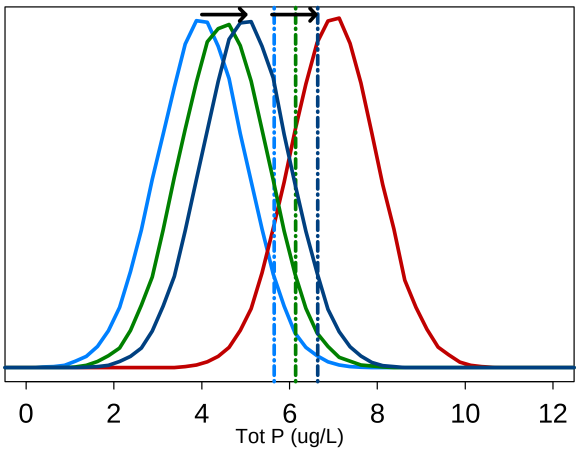

Figure 4. If the mean value of a chemical/biological element for reference sites increases towards the mean value for an impacted site, the impacted site will have a lower proportion of samples above the critical value. This implies a lower probability for detecing a real difference between the impacted site and the reference sites. In this example, as the mean Total P value for reference sites is increased by 1 µg/L (while the standard deviation in fixed), the statistical power is reduced from 91% to 64%.

Because these factors interact in complex ways to determine the capacity of a monitoring programme to detect trends in biological elements, such basic questions of "how many sites should I monitor" or "how often should I conduct surveys" rarely have intuitive answers. For example, increasing the number of sites from 1 to 2 may reduce the power (because the samples will cover more natural variation), while further increases in number of sites will generally increase the power. However, in order to have a cost-effective monitoring programme with high statistical power to detect trends it is important to evaluate how each component influences the monitoring programme's power to detect trends.

2.1.3 General statistical recommendations

The following recommendations have been drawn based on the general analyses and considerations presented above, as well as on the analyses presented in chapters 3-5.

Number of sites per type required

As a rule of thumb, 20 sites per type are recommended for estimating variance, and 10 sites per type should be the absolute minimum (see chapters 3-5). If this is not possible for e.g. financial or logistical reasons, one must consider 1) combining types (provided that the difference between types is not too large), 2) accepting a lower number of sites in some types (and consequently a more uncertain estimate of the natural variation and the risk this implies), 3) excluding types with too low site number from the monitoring design, 4) splitting types along other typology factor axes to reduce the within-type variation.

Number of sites vs. frequency

As mentioned above the number of sites and the sampling frequency required to get a sufficiently reliable estimate of the variance within and among sites, varies with the biological element tested. Phytoplankton composition and biomass show considerable seasonal variations, hence its seasonal variance is large compared to the seasonal variance of a perennial benthic species, such as macrophytes (**Figure 5**). The exception is benthic insect larvae in lakes and rivers, which also show conspicuous seasonal variation due to emergence and disappearance from the aquatic habitat during summer. The spatial variance of phytoplankton is usually less than for the benthic species, at least in reference sites. In more impacted sites this is not necessarily the case, since phytoplankton taxonomic composition is much more variable in eutrophic sites than in more oligotrophic sites (see e.g. Lyche 1990).

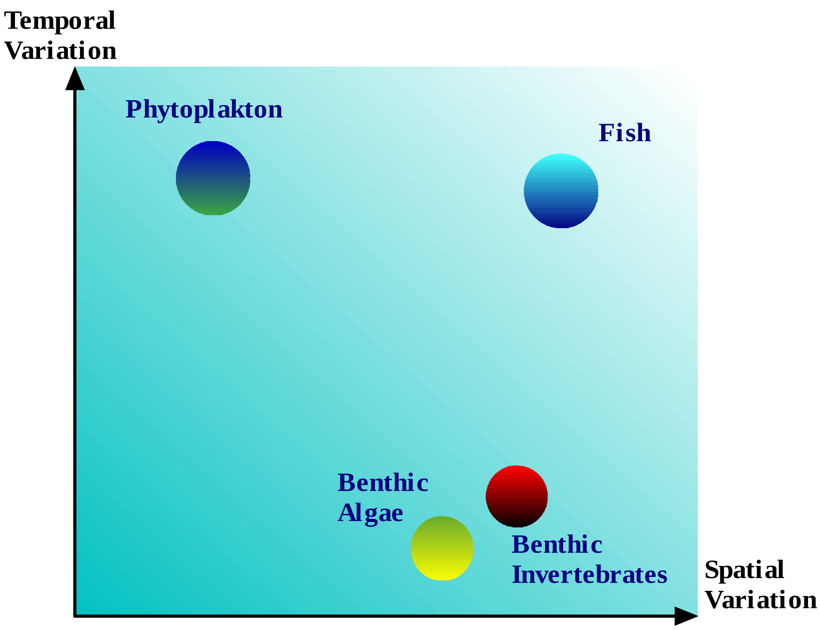

Figure 5. Relative magnitude of temporal variance versus spatial variance in the four biological elements. Benthic algae includes macrophytes in this figure. For phytoplankton the high temporal variance is due to high seasonal variance, whereas for fish the high temporal variance is due to high inter-annual variation caused by large year-class fluctuations in fish populations.

As a consequence of expected high spatial and low seasonal variation as in benthic species and fish, emphasis has to be on selecting a high number of sites, as opposed to phytoplankton with assumed low spatial and high seasonal variation, for which a high sampling frequency is more important than a high number of sites to estimate the variance.

Requirements for trend detection

The ecological significance of a trend will depend on which element is measured and what kind of measurement is used (e.g. whether an algal species is measured by total biomass, or by its proportion to the total algal biomass), as well as on the numerical boundaries between the ecological status classes relative to the reference conditions. It is therefore difficult to require a minimum magnitude of trend that the monitoring programme must be able to detect. As soon as the boundaries in the new WFD-compatible classification system have been established for the different elements, this question can be further analyzed (2006).

There are different approaches for detecting trends. One option of efficiently detecting a trend is to performe sampling on one site with several replicates or high frequency. In this way one may be able to statistically estimate significant small trends at this site. However, this approach will not enable one to infer anything about the spatial variations. Hence, this approach is not applicable in the initial phase of an optimal reference monitoring programme, but might be proficient in the subsequent monitoring phase of the programme. We recommend a combination of intensive monitoring for a few selected sites and extensive monitoring of remaining sites (see Section 2.4)

Fish has both highest spatial and inter-annual temporal variances in population parameters, and thereby requires some special considerations when designing a monitoring programme.

2.1.4 Remaining statistical 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.

- **Trend estimation**: If climatic change causes a temporal trend in the abundance of a chemical or biological element in reference lakes, this trend might be estimated by e.g. linear regression as a slope different from zero. 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. However, data for this kind of calculation are currently available only for certain biological elements and water body types.

2.2 Selection of water body types for reference sites

The main criteria applied for selection of water body types in each water category (lakes, rivers, coastal waters) have been the following:

- Types selected for intercalibration within the Northern Geographical Intercalibration Group (N-GIG) for lakes and rivers or North-East Atlantic GIG for coastal waters

- Special Norwegian types vulnerable to pressures. Examples of the latter are:
    - Very low alkalinity lakes and rivers primarily in the boreal and highland zones of Southern and Western Norway
    - Moderate alkalinity lakes and rivers in lowland zones. For this type either land-use models (applicable for both rivers and lakes) or paleoecological methods (only lakes) must be used to assess reference conditions, since there are presently very few existing sites in reference conditions (see 3.2.8 and figure 9).
    - Coastal waters in the Barents Sea region

2.3 Selection of quality elements

The biological quality elements selected for monitoring of reference sites are shown in **Table 1.**

Table 1. Biological quality elements required in the WFD for surveillance monitoring of surface waters are marked with blue shading. Dark blue shading indicate elements where Norway has long experience and high competence. Light blue shading indicate elements required in the WFD, but where there are either poor correlations between the elements and potential pressures, or a lack of competence and data in Norway. + for zooplankton indicate that this is a quality element where Norway has long monitoring traditions, long time series and regional survey data in many lakes, as well as good competence. *: Macrophytes include mosses in rivers and eelgrass in coastal waters. Benthic fauna includes littoral crustaceans, as well as profundal fauna in lakes. Benthic fauna in marine areas are mainly based on sites on soft-bottom substrates.

Biological quality elements	**Lakes**	**Rivers**	**Coastal waters**
Phytoplankton			
Benthic algae			
Macrophytes			
Benthic fauna			
Fish			
Zooplankton	+		

All biological elements required in the WFD for the different water categories are important indicators for human pressures, and have been extensively used in Norway in existing monitoring programmes, with the exception of the following elements:

- Phytoplankton in rivers
- Benthic algae in lakes
- Macrophytes other than macroalgae on soft-bottoms in coastal waters (sea grass)
- Benthic fauna on hard bottoms in coastal waters

For rivers, phytoplankton is not commonly used, due to low biomass in the mainly fast-flowing Norwegian rivers. Phytoplankton also express very high variability in rivers, which will require very frequent sampling. It is also difficult to establish dose-response relationships due to flow-related variability, as it is also stated in the WFD Guidance on Monitoring. This element is therefore only recommended in large, slow-flowing rivers, which are rare in Norway.

For lakes, benthic algae are not commonly used neither in Norway, nor within EU. No standard methods are developed, and very little experience and information exist on the use of this element in lakes. Further work is required in this area before the element can be used in standard monitoring programmes (see Guidance on Monitoring).

Zooplankton is not required for monitoring in the WFD, but has long been used for monitoring in Norway, due to its high indicator value for human impact (eutrophication and acidification), as well as for fish predation. Zooplankton affect the regression between phosphorus and chlorophyll, due to its grazing on phytoplankton. Data on zooplankton is therefore important to explain variation in the Tot-P vs. chlorophyll regressions. NIVA and NINA have large datasets from regional surveys and other monitoring programmes, and considerable competence on this element, and its ecological importance. It is therefore recommended to include zooplankton in the future monitoring of reference sites, in spite of its absence in the WFD.

Benthic fauna in lakes consists of littoral fauna (including crustaceans) and profundal fauna (mainly chironomids and oligochaetes). For the former, NINA has large datasets and good competence esp. regarding the impact of acidification and eutrophication, whereas Norway as a whole has limited competence and few data on the latter (mainly at the Univ. of Bergen).

In Norway sea grass has a very patchy distribution making the sea grass biotope less suited to monitor for regional assessments. Hard substrate invertebrate fauna is widely distributed, but has been monitored for a much shorter time compared to soft-bottom fauna, and assessment criteria needs further development .

For physico-chemical and hydromorphological supporting elements, the parameters are listed in **Table 2** (Guidance on Monitoring):

Table 2. Physico-chemical and hydro-morphological supporting quality elements required for monitoring of reference sites (see Guidance on Monitoring).

Water categories	**Physico-chemical elements**	**Hydro-morphological elements**
Lakes	Nutrients: Total-P, SRP, Total-N, NO3, NH4, Si, Acidification-relevant parameters: Alkalinity, pH, ANC, Ca Conductivity Dissolved oxygen (% saturation) Temperature Secchi depth, turbidity, colour, suspended solids	Inflow and outflow, Water level fluctuations, Mixing and circulation, Surface area, Lake volume, Etc.
Rivers	Same as for lakes	Flow, current velocity, Substrate of river bed (grain size) River depth and width River continuity
Coastal waters	Nutrients: same as for lakes Salinity Dissolved oxygen (% saturation) Temperature Light penetration & quality	Depth variation (topography) Substrate (hard rock/ soft-bottom, grain size) Direction of dominant currents, Waves, wind, tides Water column structure

2.4 Basic structure of monitoring design

Two phases of reference network monitoring are recommended:

- Phase 1 (short-term): First 6 year river basin management plan period: Intensive monitoring of all sites according to the optimal design shown for the different water categories. This phase is important in order to enable quantification of the natural variation for each element in each type of water body. Today this variation is virtually unknown for most types of water bodies and many elements, since most past and present monitoring in Norway has been focused on impacted sites.

- Phase 2 (long-term): Subsesquent 6 year periods: Two levels of monitoring should be done:
    - Intensive monitoring of a limited number of sites according to optimal sampling design (as in phase 1). Minimum three sites per type are recommended.
    - Extensive monitoring of the large majority of sites according to the minimal sampling design for each water category.

In phase two the intensive programme with high frequency of observations in a limited number of sites will provide detailed knowledge of ecosystem structure and function, which can be used to assess trends due to climate change (baseline changes). The data collected in the extensive programme can be used to assess spatial variability and large regional trends.

The two levels proposed for phase two represent the same practice as has been used in the national acidification programme for many years.

2.5 Costs for first and second phase of monitoring programme

A crude tentative budget has been constructed for all the water categories, showing the costs for the two phases of the monitoring programme described above. The budget input is taken from the separate chapters for the three water categories. There are many uncertainties in the budget, and this should thus be regarded as preliminary. Still it may represent the right order of magnitude for the financial needs for a monitoring programme for reference sites.

The budget shows a need for 140 mill. NOK per year during the first 6-years monitoring period, in order to establish the baseline for all elements, types and water categories. The distribution of resources will be roughly 35% for the two freshwater categories (rivers and lakes) and 65% to marine water bodies in coastal areas. During the next phase, i.e. the consequtive 6 year periods the annual costs will decrease towards roughly 28 mill. NOK, with a more even distribution between the two freshwater categories and the coastal waters (45% and 55% respectively.

Today the annual cost for all monitoring in Norway, including freshwater, marine, air and terrestrial monitoring is roughly 80 million NOK, whereas Denmark, who has roughly one order of magnitude fewer water bodies than Norway, spends annually 120 million DKK for freshwater monitoring only (Jeppesen and Andersen, NERI pers. comm..).

Table 3. Tentative budget for monitoring of reference network for all water categories (see text for explanation). Costs given in 1000 NOK.

Water category	1st phase* annual cost	1st phase* total cost for first 6 years period	2nd phase** annual costs for each year following the first 6 years period	2nd phase** total cost for each of the following 6 years periods
Lakes (see section 3.2.7)	30000	180000	7500	45000
Rivers (see section 4.2.7)	20000	120000	5000	30000
Coastal waters (see section 5.2.7)	90000	540000	15000	90000
Sum for all categories	140000	840000	27500	165000

* First phase: All sites following the optimal design (see chapters 3, 4 and 5)
** Second phase: 3 sites per type following the optimal design, the large majority of sites following the minimal design. See also section 2.4.

2.6 Co-localisation and synergy effects

Synergies are possible between the reference network monitoring in lakes and the existing coordinated national lake monitoring programme for acidification and toxic substances. There are 102 lakes in common for these two programmes (Skjelkvåle pers.comm.), of which 36 have biological monitoring (zoological quality elements only). Synergies are also possible with NVE's monitoring of water level fluctuations, but the number of sites overlapping between these two programmes have not been investigated yet.

For rivers, the obvious synergy is the overlap between the reference network proposed in this report and the annual monitoring of the reference river Atna, which has been going on for 15 years. Another possible synergy for rivers monitoring is to combine the reference network with the current Riverine Inputs and Direct Discharges (RID) monitoring programme, in which physico-chemical and some hydromorphological elements are measured. From the list of rivers proposed in Appendix B roughly one third are included in RID, but the RID stations are at the outlet of the rivers, which in many cases cannot be expected to be in reference conditions.

To optimize the output and lower the cost of the coastal reference programme, the sites selected are partly included in existing and other proposed marine monitoring/surveillance programmes, such as the *National monitoring program of coastal marine biodiversity* ("Nasjonal overvåking av marint biologisk mangfold i kystsonen"(Nygaard et al. 2004), *European marine biodiversity reseach sites* (BIOMARE-programme)(Warwick et al. 2003), *The coastal monitoring program* (Pedersen & Rygg, 1990) as well as the *Marine protected areas in Norwa: Design input of a new national plan* ("Rådgivende utvalg. Råd til utforming av marin verneplan for marine beskyttede områder i Norge") (Skjoldal et al. 2003).

For all water categories, synergies are also possible between comparable reference monitoring programmes that will be planned in other Nordic countries who share the same types of water bodies. A separate project funded by the Nordic Council of Ministers is aiming at using comparable design for reference monitoring across the Nordic countries, and thus enable a reduction of the number of sites necessary for each common type in each country. This will be discussed further in coming workshops among the Nordic countries in the context of Intercalibration of Ecological Assessment methods.

3. Lakes

3.1 Methods

3.1.1 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 Solheim et al. 2003). The results compiled from the characterisation of water bodies performed in 2004 (NVE pers. comm.) for these 500 lakes, have been used to discard lakes from this list that are either acidified, heavily modified, or classified as "at risk" or "possibly at risk" of failing to achieve the WFD objective of good status. Lakes without typology data have also been discarded. 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 designated as "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 126 lakes (**Table 5** below), additional lakes will be needed for many lake types in many ecoregions (see chapter 3.2), in order to obtain acceptable statistical power (see Chapter 2 and 3.1.3 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 designated to be "not at risk" should enable a future selection of sufficient number of lakes for most lake types.

3.1.2 Chemical and biological datasets used for statistical testing / recommendations

<u>Chemical parameters</u>
Analyses of spatial variation in total phosphorus concentration were based on the dataset "RESA", originating from a national lake survey in Norway carried out in 1995 (Skjelkvåle et al. 1995). Altogether 1500 lakes, not influenced by local pollution, were sampled. Most of these lakes were selected by a size-stratified, statistically representative sampling scheme in order to get a representativ selection of lakes. 500 new lakes were added as a follow up of the 1000 lakes survey (1986) in order to follow trends in water chemistry. 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.

<u>Phytoplankton</u>
Analyses of spatial variation in phytoplankton were based on the dataset "EUREGI" originating from the Norwegian eutrophication survey 1988-2001, reported in Oredalen & Faafeng 2002. The data consist of > 2500 samples from > 400 lakes, covering the whole eutrophication gradient. Phytoplankton has mostly been identified to species level for all samples. Biological metrics used for the statistical testing are total algal biomass, proportion of Cyanobacteria (tolerant to eutrophication) and proportion chrysophytes (sensitive to eutrophication). Reference sites have been selected by expert judgement (Brettum pers. comm.), and have low phytoplankton biomass and a species composition consisting of taxa mainly occurring in oligo- or slightly mesotrophic lakes. This selection should be checked

against the results of the risk assessment performed in the characterisation projects (WFD Article 5), but this has not been possible in the present project.

Table 4. Number of reference lakes per lake 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 phytoplankton biomass were based on a 14-years time series from Lake Atnsjøen, which is an ultraoligotrophic lake used for monitoring of reference conditions.

Microcrustaceans

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 includes only presence/absence 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 Characterisation 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 programme 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.

Fish

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 regulated lakes that were (Reg=2) were discarded from the dataset, whereas 154 lakes were retained. 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 char from Lake Atnsjøen.

3.1.3 Brief description of methods used for statistical testing

Number of sites per lake type

Chemical parameters and phytoplankton

Increasing the number of sites per lake type will increase our knowledge on how reference sites vary under natural conditions. Increasing the number of sites thus increases the precision in the estimate of variance, and thus increases the probability of detecting deviations from reference conditions. However, power analyses cannot be used directly to select the number of reference sites at this stage, because this requires information about how large differences should be detected between reference and impact sites, and about the natural variation within

impacted sites and refernce sites. We have therefore focused on characterizing 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 (phytoplankton biomass, proportion of cyanobacteria, proportion of chrysophytes):
1) Select a range of number of reference sites (e.g. n = 5, 10, 15,… 50)
2) For each n, select 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 indicate how the fact that we increase the number of sites increases our confidence about the estimates of natural variation. This will in turn increase our ability to correctly detect differences between reference sites and impacted sites.

Microcrustaceans
Spatial variation in species composition was analysed by an ordination technique; Detrended Correspondence Analysis (DCA). 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).

Fish
Initially we used scatter plot to check if 1) lake-size or fish introductions have 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 were 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 therefore pooled in the further analyses.

Sampling frequency and minimum number of years of observations

Phytoplankton
A higher number of observations per year give 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 both the sampling variation (which should be minimized), as well as the natural variation (which cannot be reduced). Higher frequency of samples per year also enables us to better account for seasonal variation.

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.

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

Fish
Data from benthic gill-nets, 0-10 m and pelagic gill-nets, 0-6 m were analyzed for trout, whereas only data from benthic gill-nets, 0-10 m were used in the analyses of char. We assume that the temporal variance due to changing environments acts 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 of more than one year, we must necessarily expect dependence between observations. The environmental variance can then be estimated by Equation (2), Section 2.1.1. 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 can use a more direct approach, and estimate the environmental variance as $\mathrm{Var}(x)/\mathrm{E}(x)^2$, where x is the abundance.

3.2 Results

3.2.1 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 the six different ecoregions, the number of lakes in the RN would be very high, if all lake types were to 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 3.2.8 on “remaining issues”.

The lake types prioritized in the proposed RN are those selected for intercalibration (IC) in the Northern Geographical Intercalibration Group (N-GIG) (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 specifically 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 11 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).

3.2.2 Occurrence of reference lakes in different regions and types

To restrict the number of lake types as much as possible, we propose to give priority to those geological types that are assumed to be commonly occuring 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 108 types (6 ecoregions x 3 altitude regions x 6 geological types), see **Table 5**. This assumption should be checked after the addition of more reference lakes from the results of the characterisation projects in the next phase of this project.

The distribution of the 126 selected reference lakes (**Table 20**, Appendix A) among the different regions and selected basic types are shown in **Table 5**. As can be seen from the table, the large majority of the selected lakes (122 lakes) belong to one of the prioritized lake types.

Table 5. Distribution of selected reference lakes among different regions and types. Yellow fields show prioritized lake types. The list of reference lakes are shown in **Table 20**, Appendix A.

		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	1	0	3	7	1	0	12	11
	Highland	3	0	2	0	0	0	7	7
Southern	Lowland	2	0	0	1	0	0	3	3
	Boreal	3	0	0	1	0	0	4	4
	Highland	2	0	2	0	0	0	4	4
Western	Lowland	8	0	15	0	0	0	23	23
	Boreal	13	0	4	1	0	0	18	18
	Highland	1	0	2	0	0	0	3	3
Central	Lowland	1	0	0	1	0	0	2	1
	Boreal	6	1	3	0	0	0	10	9
	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		42	1	45	22	9	7	126	
Sum prior.		41		45	22	8	6		122

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 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) designated to be “clearly not at risk” according to the results from the characterisation work (Stalsberg, NVE pers. comm.) (see section 3.2.8 and remaining issues below). More reference lakes should be added from a list of these lakes as soon as possible.

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

To assess the number of reference sites per lake type necessary to reduce the spatial variation to an acceptable level, 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 (phytoplankton biomass and taxonomic composition) **Figure 6**. In general the figure shows a sharp decline in variation (i.e. an increase in precision) from 5 to 10 sites, 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 gradually smaller than from 10 to 20 sites. Analyses of the chemical elements show similar patterns (not shown). From these curves we recommend 20 sites per lake type as the optimal number of sites and 10 sites as a minimum.

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 indicates that the variance (CV in %) decreases clearly with increasing number of lakes up to approximately 10 lakes. Somewhere between 15 and 25 lakes the decrease in variance is levelling out. This concurs with the pattern of the phytoplankton analysis above.

Assessment of spatial variance in trout populations show that lakes in eco-region Northern Norway, coastal parts have a significant smaller mean CPUE (17.9 per 100 m^2) than lakes in all other regions (31.5 – 40.2 per 100 m^2). No data exist from Northern Norway, inland parts. Mean CPUE in Eastern Norway (40.2 per 100 m^2) is significantly higher than in Western Norway (31.5 per 100 m^2) 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 have uncertain ecological status, although the water quality may be good (liming, acidification). We found no significant differences between boreal and highland lakes in mean CPUE (pooled mean: 32.6, variance: 21.5). Still, there may be differences between these categories, but the quality of the data prevented us from proving it (the effect of Altitude was confounded with the effect of Ecoregion). In addition, the age structure may differ between boreal and highland lakes (see Facta sheet for reference conditions). Following the general guidelines, we recommend 20 sites per lake type as the optimal number of sites and 10 sites as an absolute minimum. If this is not possible we recommend to combine types, provided that the difference is not too large, rather than reducing the number of sites per type.

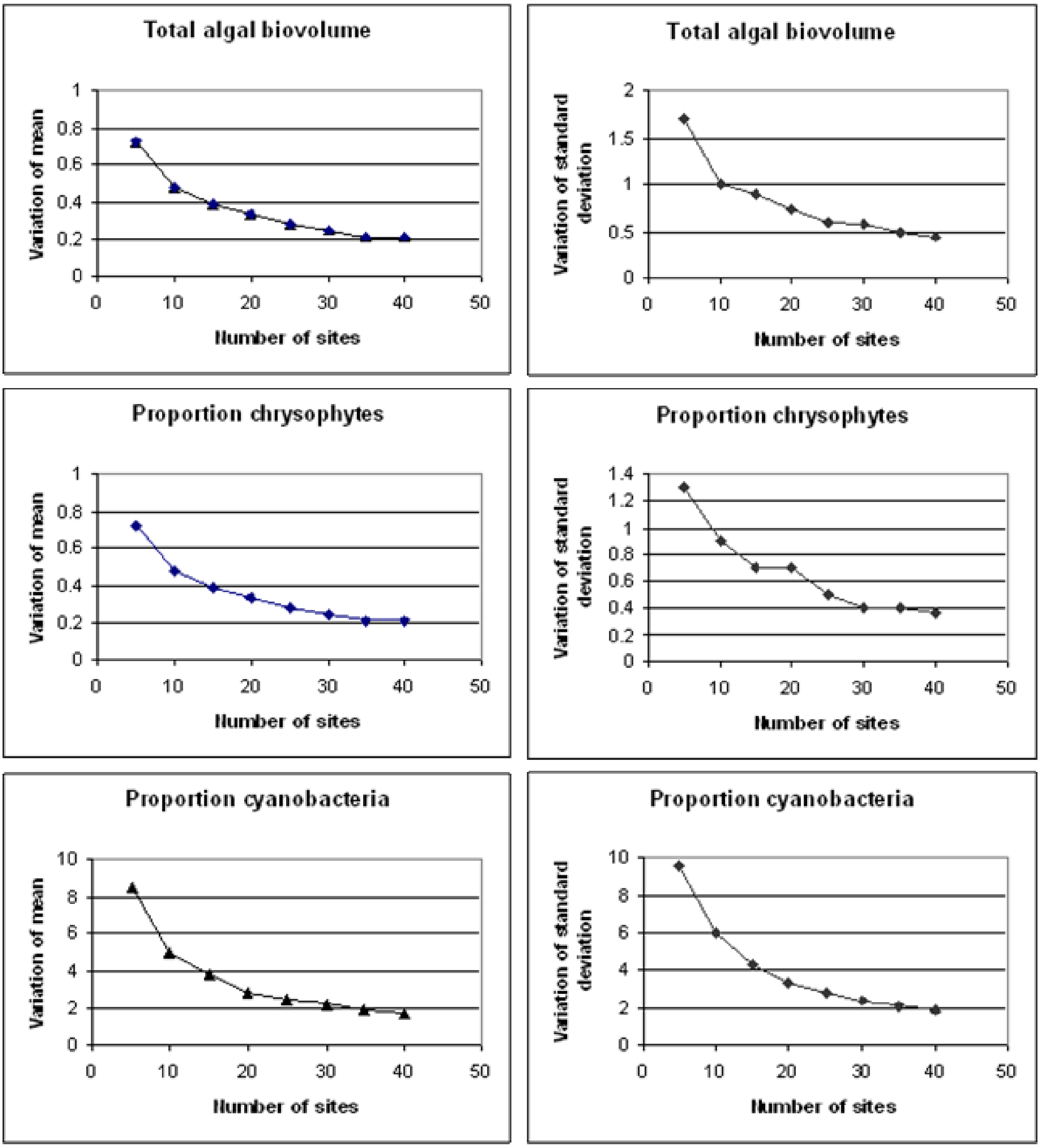

Figure 6. Statistical analyses of phytoplankton from low-alkalinity clear water lakes. For each number of sites (*n*), *n* sites is randomly sampled 250 times and the mean and standard deviation is calculated for each set of *n* sites. The figure shows how the precision for estimated mean and standard 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 the lower 2.5% quantiles.

3.2.4 Statistical testing of sampling frequency

Phytoplankton

The importance of sampling frequency (number of samples per year) for the precision of estimates is illustrated in **Figure 7** and **Figure 8**. The latter figure 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 ultraoligotrophic lake. Lakes with somewhat higher trophic status usually have higher seasonal variation, thus requiring higher sampling frequency.

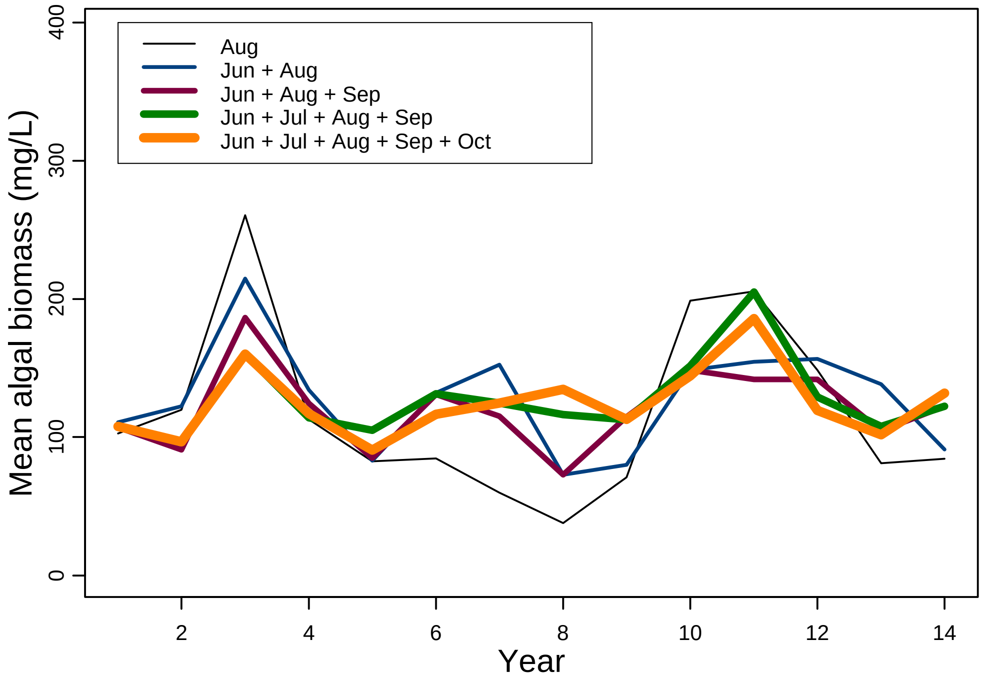

Figure 7. Interannual variation of mean seasonal phytoplankton biomass per year for Lake Atnsjøen 1988-2002. The curves indicate how the interannual variation is reduced with the increase of sampling frequency from 1 to 5 monthly samples per year.

Calculations by Faafeng & Fjeld (1996) show how the relative uncertainty decreases with sampling frequency, but also increases with mean chlorophyll a. For example, for lakes in status class I (Tot-P: < 7 µg/L and chlorophyll a < 2 µg/L according to the existing classification system in Norway), increasing the sampling frequency from 4 to 10 per year reduces the uncertainty from 39% to 25%. For lakes in status class III (Tot-P: 11-20 µg/L and chlorophyll a: 4-8 µg/L), however, the uncertainty will be 50% to 32% for 4 and 10 samples per year, respectively.

Based on these analyses we recommend 10 samples per year for phytoplankton as the optimal design for all lake types with low alkalinity (probably comparable to status class I in the existing classification system), and even higher frequency for moderate alkalinity lakes (probably having a reference condition higher than status class I for chlorophyll). As a minimum design 5 samples per year can be tentatively recommended.

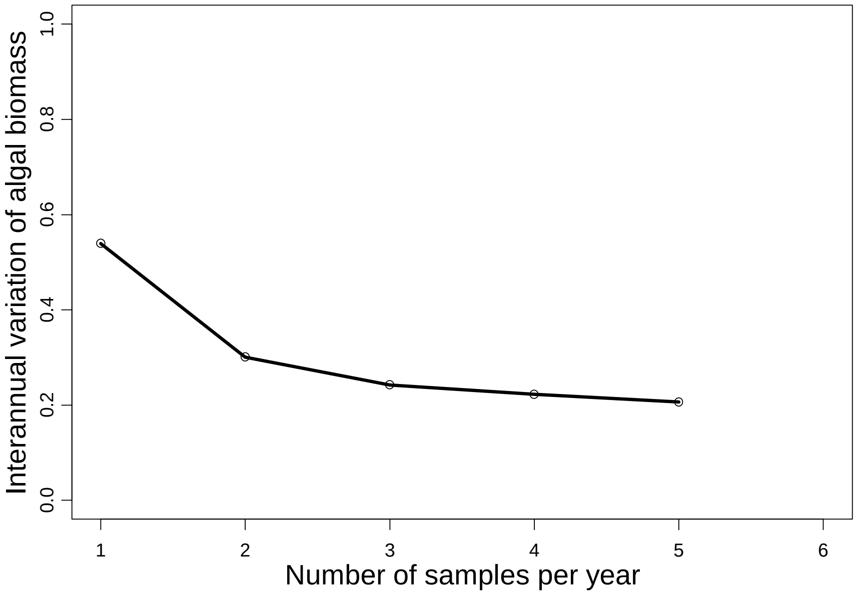

Figure 8. Interannual variation, measured as the coefficient of variation (standard deviation scaled by mean), as a function of the number of samples per year or season.

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 focuses on common species, as well as the presence of sensitive versus tolerant species it seems that only a few years of observations (e.g. 3 years) are sufficient to provide a reliable general characteristic of the microcrustacean community at a given site.

Fish
The two approaches for estimation of temporal variance in the trout population of Lake Atnsjøen gave relatively similar results (0.075 vs. 0.070), whereas the estimates for the char population were rather different (0.53 vs. 0.73). The results indicate that the independence assumption is further from the truth for the char than for the trout population.

Based on these analyses we recommend at least three years of monitoring within the first six years monitoring period (optimal design). This design should be kept for a limited number of sites per type also in consecutive monitoring periods (see section 2.4).

3.2.5 Selection of elements and recommendations of sampling frequency

The elements to be included in RN monitoring are given in Vedlegg 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 (see also chapter 2.3). The list of elements selected is shown in **Table 6**.

Table 6. 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	Twice monthly during growth season	Monthly in growth season
Biomass (chlorophyll and biovolume)	(10/year, April-Oct)	(5-6/year, May-Oct)
Diversity (evenness)		
Macrophytes	**Every 2 years**	**Every 6 years**
Taxonomic composition	1/year (July-September)	1/year (July-September)
% cover		
Lower growth limit		
Diversity		
Zooplankton	**Every 2 years**	**Every 6 years**
Taxonomic composition	3/year (June, Aug, Oct)	3/year (June, Aug, Oct)
Abundance (population density or biomass)		
Diversity		
Benthic fauna (littoral)	**Every 2 years**	**Every 6 years**
Taxonomic composition	2/year (May + October)	1/year (October)
Abundance		
Diversity		
Fish	**Every 2 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) (daily during high flow)	Weekly (automatic) (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.

3.2.6 Selected reference lakes

The selected reference lakes are shown in **Table 20**, 7.Appendix A. and in **Figure 9**. 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 **Table 7**. The table is based on the ecoregions and the 11 basic types identified above (see 3.2.2).

Not all elements differentiate between all the ecoregions and all the basic types, and the number of types can therefore be reduced accordingly. Phytoplankton has not been shown to differentiate between ecoregions, altitude regions nor between very low and low alkalinity lakes. Thus this element only shows significant differences between the four basic types, which are combinations of low and moderate alkalinity and low and high humic content. Macrophytes seem not to differ between the two Northern ecoregions, nor between lowland and boreal (M. 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 differentiate between very low and low alkalinity and humic content, but not between low and moderate alkalinity, although this has not yet been shown statistically for Norwegian data.

Table 7. Total number of types and sites 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. The number of lake types for each element is calculated from a combination of the prioritized types shown in **Table 5** and the variation of each element among ecoregions and basic types.

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	31	620	310	difference between ecoregions, difference between highland and lower altitude regions
Macrophytes	5	7	31	620	310	difference between ecoregions, difference between highland and lower altitude regions
Benthic fauna* (only littoral)	5	11	43	860	430	difference between ecoregions and between all the three altitude regions
Fish	6	7	39	780	390	difference between ecoregions and between all the three altitude regions

*Profundal fauna should be evaluated in the next project phase

The maximum number of lakes to be selected for the optimal design is thus 860, whereas for the minimal design is 430. 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 accordingly.

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.

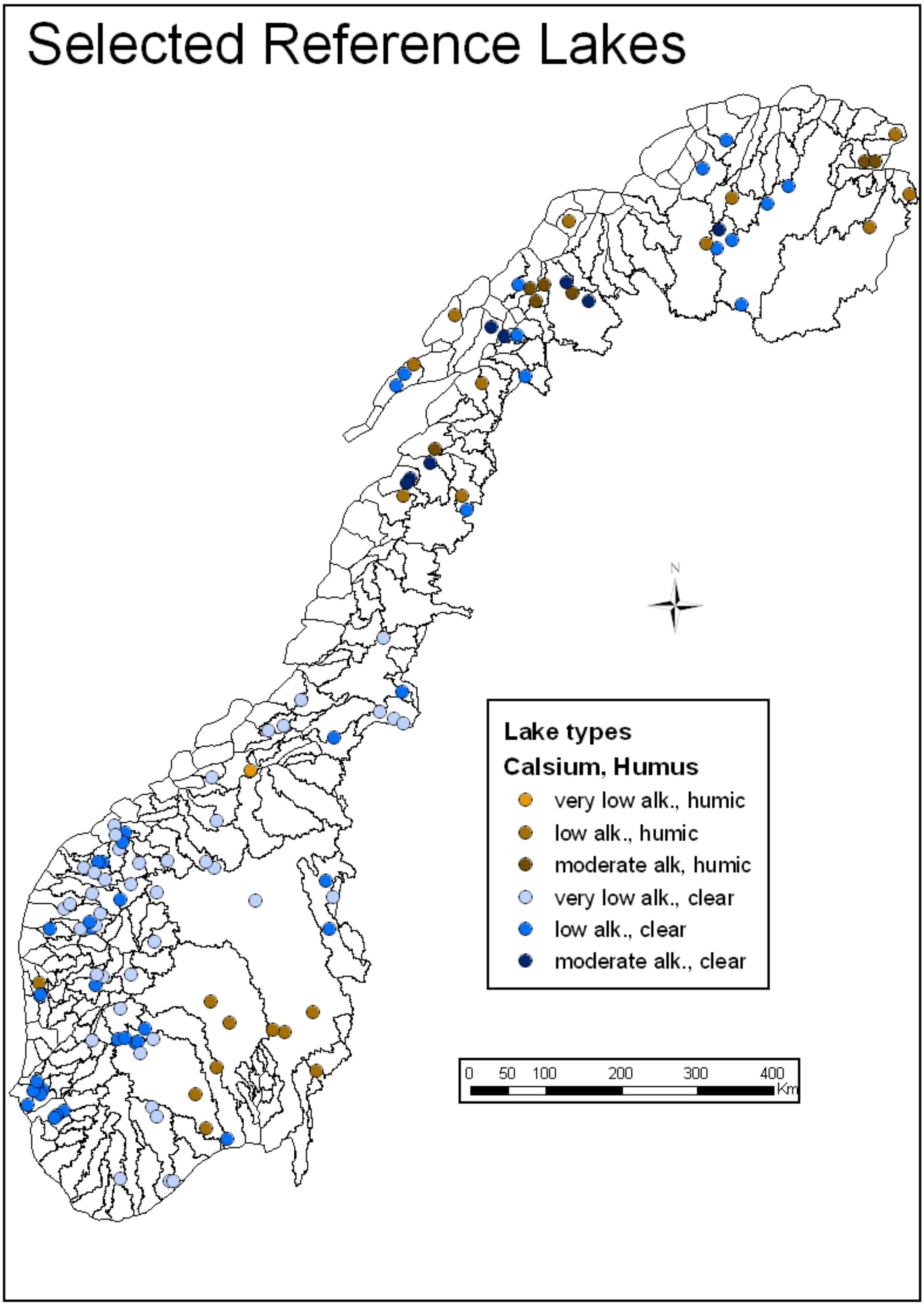

Figure 9. Selected reference lakes. Lines show borders of main watersheds

3.2.7 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 (see also section 2.5). The optimal design applies 20 sites per type and applies a higher sampling frequency, whereas the minimal design applies 10 sites per type and applies a lower sampling frequency (see **Table 8**).

Table 8. Cost estimate for monitoring of reference lakes. For optimal design we have used 20 sites per type, and for the minimal design, 10 sites per type, according to the recommendations based on the statistical analyses in **Figure 6**. The optimal and minimal number of lakes is taken from **Table 7** and the optimal and minimal sampling frequency and monitoring interval from **Table 6**. This is used to estimate the total costs per 6 years period, and then the annual costs are given as one sixth of this.

		Optimal design			Minimal design		
Activity	Cost per sample	Cost per lake per year	Total annual costs*	Total costs per 6 year period*	Cost per lake per year	Total annual costs*	Total costs per 6 year period*
Sampling, analyses							
Physico-chemical elements, incl. observations of water level fluctuations	4	40	3200	19200	20	267	1600
Phytoplankton	4	40	3200	19200	20	267	1600
Zooplankton	4	12	3720	22320	12	620	3720
Macrophytes	16	16	4960	29760	16	827	4960
Benthic fauna (littoral)**	8	16	6880	41280	8	573	3440
Fish	16	16	6240	37440	16	1040	6240
Total for sampling and analyses	52	140	28200	169200	92	3593	21560
Reporting			800	1600		600	600
Coordination and administration			200	1200		150	300
Total costs excl. VAT	52	140	29200	172000	92	4343	22460
Total costs minus zooplankton	48	128	25480	149680	80	3723	18740

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

The optimal design is estimated to roughly 30 mill. NOK per year, and 150-180 mill. NOK for the first 6 year RBMP (River Basin Management Plan) period. This optimal design is recommended for the first six years 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 minimal design is estimated to roughly 4 mill. NOK per year and 22 mill. NOK for each successive six years period. In this design only the phytoplankton and water chemistry are proposed to be monitored twice during the six year period of the RBMP. 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.

3.2.8 Remaining issues - lakes

- **Addition of more sites:** The number of reference lakes in most of the regions and types is 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 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 is made.

- **Models and paleoecology:** For lake types with few existing sites, other methods for estimating their reference conditions should be attempted:

    - 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 20 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. Also land-use models to estimate background load of phosphorus and reference Tot-P-concentration can be attempted as an alternative method for assessment of reference conditions for this lake type.

    - For lakes with very low alkalinity in the Southern ecoregion, where the large majority of lakes are acidified, new models may be used (Hindar and Wright 2002).

- **Northern-GIG collaboration:** The number of lakes selected for reference conditions monitoring in Norway can be reduced through collaboration in the N-GIG for at least some of the IC-types. This will have to be discussed further at the coming workshops in the N-GIG in April and September 2005.

- **Links 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, see also chapter 2.6.

- **Further needs and possibilities for statistical testing for crustaceans and fish**

- 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 discarding impacted sites (with help of the results from the Characterisation 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 char), Lake Femunden (23 years, whitefish) and Lake Høysjøen (19 years, trout and char), representing two different lake types 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 is necessary for the datasets from Femunden and Høysjøen before further analyses.

4. Rivers

4.1 Methods

4.1.1 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), supplemented with rivers from various biological studies. The reference status of the rivers has been checked by applying the results from the Characterisation Projects performed in 2004 (status per February 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.

Some additional rivers, from which potential reference-sites may be selected, have been suggested after input from various research institutes in Norway (expert judgement). The reference status of these rivers has to be checked by applying the results from the Characterisation Projects, but information on river type and ecological status has not been available within the time limits of this project.

4.1.2 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 databases on macroinvertebrates and benthic algae from Norwegian rivers, which are managed by NINA and NIVA, include >1500 sites, representing > 500 rivers, covering the whole country. Both impacted, as well as non-impacted rivers are included in these databases. The data are based on various sampling methods and -efforts, 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 later in 2005 through the further development of the databases.

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

In 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.

4.1.3 Brief description of methods used for statistical testing

Benthic algae from the 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 site 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).

4.2 Results

4.2.1 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 which are likely to be vulnerable to pressures such as eutrophication (all lowland rivers) and acidification (very low and low alkalinity rivers).
- Other river types which are common in Norway but not necessarily in the rest of Europe.

According to this 11 basic river types are proposed to be included in the RN. These river types are equivalent to the basic lake types presented in section 3.2.1.

Some of these river types are not commonly occuring in all the six eco-regions, and thus should not be given priority in the reference network. The total number of types therefore can be reduced accordingly. Examples of types that are expected to be are very low alkalinity rivers in Central Norway and in the two northern eco-regions, and moderate alkalinity humic rives in the three southern eco-regions. These types will therefore not be prioritized in the design of the reference network for rivers.

The river types suggested to be of high priority are presented in colours in **Table 9**.

4.2.2 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 water-bodies designated as not at risk of failing the objective of good status. (**Table 9** and **Table 21, Appendix B**). For most of the rivers more than one river-type and more than one water-body per type was identified, resulting in a total number of 32 river types and 90 river sites. Some additional rivers, from which potential reference-sites may be selected, are presented in **Table 22, Appendix B**. The total number of reference sites, based on the output from the Characterisation Projects, is expected to be much higher. However, the complete and updated dataset from the Characterisation Projects have not been made available for this project.

Table 9. 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 Characterisation Projects. All size-categories (<10 km^2, 10-1000 km^2, >1000 km^2) are represented (see **Table 21**). 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. Six of the river sites presented in **Table 21** are not typified and therefore not included in this table. The number of potential reference sites should be increased after further investigation of the output from the Characterisation project.

Egoreg	Altitude	Very low alk		Low alk		Moderate alk	
		clear	organic	clear	organic	clear	organic
Eastern	Lowland				1		
	Boreal			5	4		
	Highland	2					
Western	Lowland						
	Boreal	3					
	Highland	4					
Central	Lowland			3			
	Boreal			12	1	2	
	Highland			2		2	
Northern - coast	Lowland						
	Boreal			1	1[1]		
	Highland			1	1[1]		
Northern - inland	Lowland			2	1	1	
	Boreal			2	12	2	9
	Highland			6	1	1	2

[1] *Not humic, but glacier impacted river sites*

The highest number of sites was found for low alkalinity, clear rivers in all climate regions, covering Central Norway and the inland parts of Northern Norway. Boreal, low alkalinity, humic rivers are also common in several of the ecoregions. A substantial part of the river-sites belong to the very small size category. These river types are not included among common river types in Lyche Solheim & Schartau (2004). No reference sites were found in Southern and South-Western Norway, due to acidification, and the number of reference sites are also expected to be low in the coastal part of Northern Norway due to river regulations. 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.

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.

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

From the studies in the 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 programme. 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.

4.2.4 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 throughout 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 the 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 programme 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 the 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 supports the general impression that the environmental conditions are 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).

4.2.5 Selection of elements and sampling frequency

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

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

Of the quality elements mentioned in Vedlegg 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.

Table 10. Selection of elements and parameters and recommended sampling frequencies for RN monitoring of rivers. Coloured cells indicate minimal requirements.

Quality elements	Optimal sampling frequency	Minimal sampling frequency
Benthic algae	**Annually**	**Every 3 years**
Taxonomic composition	2/year (August/September)	1/year (August/September)
Abundance		
Indicator species		
Macrophytes and mosses	**Every 2 years**	**Every 6 years**
Taxonomic composition	1/year (July-September)	1/year (July-September)
Abundance (% cover)		
Indicator species		
Macroinvertebrates	**Every 2 years**	**Every 6 years**
Taxonomic composition	2/year (May + October)	1/year (October)
Abundance (% or individuals)		
Diversity		
Fish	**Every 2 years**	**Every 6 years**
Taxonomic composition	1/year (August/September)	1/year (August/September)
Abundance (CPUE)		
Age structure (+ growth)		
Physico-chemical quality elements	**Annually**	**Every 3 years**
Tot-P	12/year (weekly during floods)	5-6/year (all seasons)
Tot-N and NO3	12/year (weekly during floods)	5-6/year (all seasons)
Colour (TOC)	12/year (weekly during floods)	5-6/year (all seasons)
Turbidity	12/year (weekly during floods)	5-6/year (all seasons)
pH	12/year (weekly during floods)	5-6/year (all seasons)
Ca	12/year (weekly during floods)	5-6/year (all seasons)
Alk (ANC)	12/year (weekly during floods)	5-6/year (all seasons)
Temperature	Continuous	5-6/year (all seasons)
Hydrological quality elements	**Annually**	**Annually**
Water flow	Continuous (alternatively neighbouring watercourses)	Continuous (alternatively neighbouring watercourses)
Time and duration of ice cover	Continuous (alternatively event-based)	Continuous (alternatively event-based)
Hydromorphological quality elements	**Every 6 years**	**Every 6 years**
River depth and with variation	4 (all seasons)	4 (all seasons)
Structure and substrate of river bed	1 (July/August)	1 (July/August)
Structure of riparian zone	1 (July/August)	1 (July/August)

All the prioritized biological quality elements are included in the national monitoring programme on liming, and macroinvertebrates and fish are included in the national monitoring programme on acidification. Assessment of local pollution (organic pollution and industrial effluents) is mainly based on monitoring of macroinvertebrates and benthic algae. Impacts of hydromorphological pressures have been studied by monitoring of benthic algae, mosses, macrophytes (slow flowing river sections), macroinvertebrates and fish.

Chemical, physio-chemical, and hydromorphological quality elements according to Vedlegg 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 **Table 10.**

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

The number of "types" varies between quality elements. **Table 11** 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.

Table 11. Total numbers of river types and sites (optimal and minimal design) to be included in the RN monitoring for rivers. The typology criteria are presented in Lyche Solheim et al. (2003) and Lyche Solheim & Schartau (2004). The optimal and minimal numbers of sites are based on 20 or 10 sites per river type, respectively (see statistical analyses above). The number of river types for each element is calculated from a combination of the prioritized types shown in **Table 9** and the variation of each element among ecoregions and basic types.

Quality element	Ecoregions	Altitude+ chemistry (basic types)	total # river types[2]	optimal # sites	minimal # sites	comment
Benthic algae[1]	4	11	23	460	230	no difference between Eastern and Western ecoregions, difference between all three altitude regions
Macrophytes and mosses[1]	5	11	21	420	210	difference between ecoregions, difference between highland and lower altitude regions
Macroinvertebrates[1]	5	11	29	580	290	difference between ecoregions, difference between all three altitude regions
Fish[1]	6	9	24	480	240	difference between ecoregions, difference between all three altitude regions, no difference between low and moderate alkalinity
Water chemistry[2]	1	5	5	100	50	no difference between ecoregions, no difference between altitude regions

[1] The biological communities of rivers <10 km2 (VS: very small) may be significantly different from larger rivers. If very small rivers are included as separate river types, the number of sites has to be doubled.
[2] For chemical monitoring we suggest to include one site per river-type per river (in average approximately one sampling station per 5 sites).

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. For a given type each eco-region where the type is present should be represented in the reference network. Most types are, however, represented in only two or three eco-regions. 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 programme. Priority should be given to rivers with more than one river-type present.

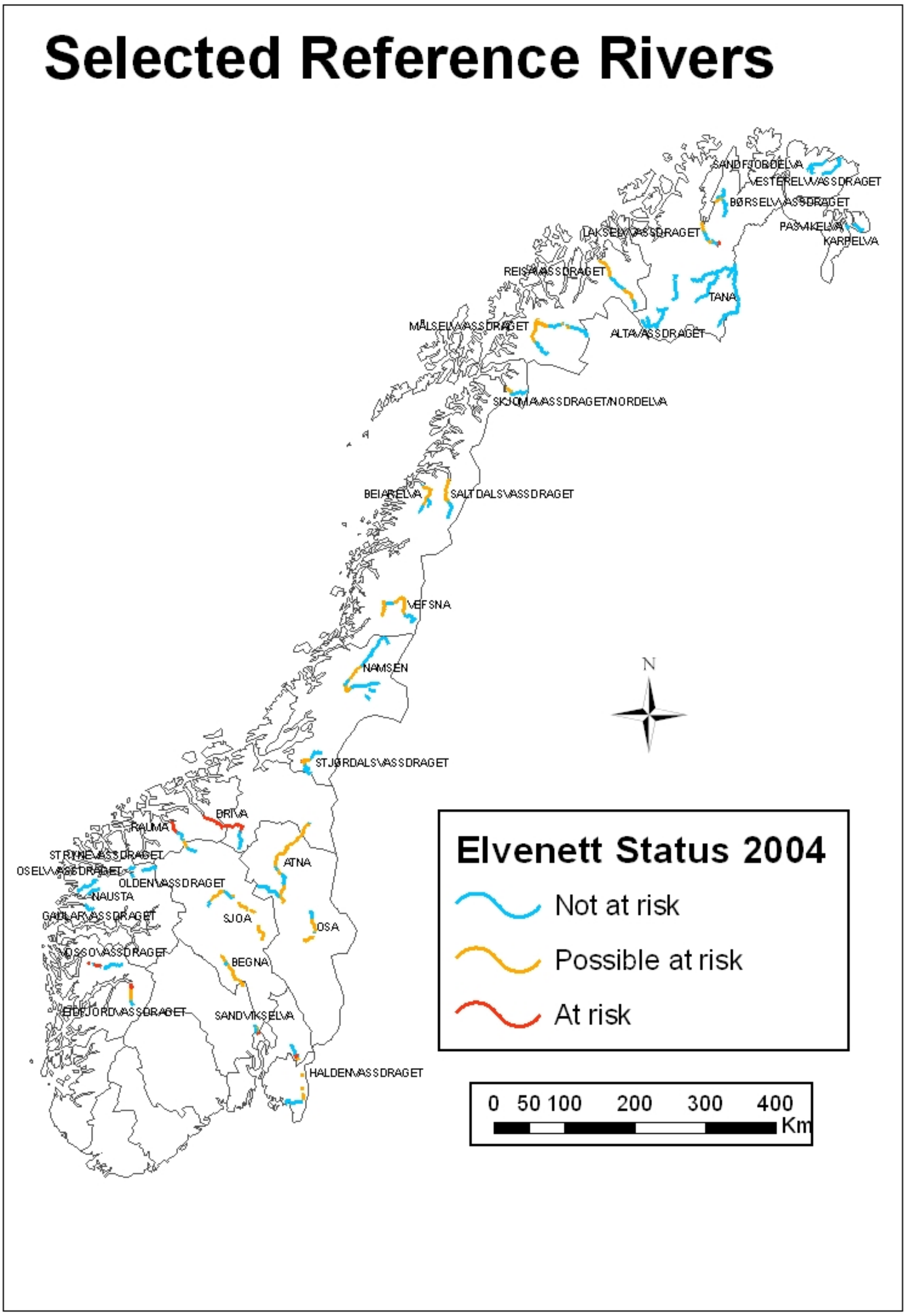

Figure 10. Potential reference rivers including rivers presented in Lyche Solheim et al. (2003) which are designated as "not at risk" according to the results from the Characterisation projects (see also **Table 21, Appendix B**).

4.2.7 Cost estimate rivers

Alternative budgets (optimal and minimal design) including man-power and direct costs (travelling, equipments etc.) are presented in **Table 12**. The optimal design is based on an intensive sampling of all selected sites, (c.f. **Table 11**) following optimal sampling frequency (c.f. **Table 10**) whereas the minimal design is based on sampling of a minimal number of sites following minimal sampling frequency. All costs presuppose co-ordination of the fieldwork for all quality elements and rivers.

Table 12. Cost estimate rivers, optimal and minimal design (in 1000 NOK). **Optimal design:** Two yearly samples of benthic algae (quantitative+qualitative), 1 yearly sample of macrophytes, two yearly samples of macroinvertebrates (qualitative), 1 yearly sample of fish (including age analyses), 20 sites of each river type.
Minimal design: 1 yearly sample of benthic algae (quantitative+qualitative), 1 yearly sample of macrophytes, two yearly samples of macroinvertebrates (qualitative), 1 yearly sample of fish (including age analyses), 10 sites of each river type.

		Optimal design			**Minimal design**		
Activity	Cost per sample	Cost per river site per year[1]	Total annual costs[2]	Total costs per 6 year period[2]	Cost per river site per year	Total annual costs[2]	Total costs per 6 year period[2]
Sampling, analyses							
Physico-chemical elements	2	24	2400	14400	12	200	1200
Hydromorphological elements	9	9	870	5220	9	150	900
Benthic algae	9	18	8280	49680	9	345	2070
Macrophytes and mosses	7	7	1470	8820	7	245	1470
Benthic fauna	9	18	5220	31320	9	435	2610
Fish	6	6	1440	8640	6	240	1440
Total for sampling and analyses	42	82	19680	118080	52	1615	9690
Reporting			800	1600		600	600
Coordination and administration			200	1200		150	300
Total costs excl. VAT	40	58	20680	120880	52	2365	10590

[1] Costs per sampling year are given (Note: some quality elements are not monitored every year)
[2] Total costs indicate the total costs for monitoring of all the sites.

4.2.8 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 the 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

- **Addition of more sites**: The numer of river-sites in most of the ecoregions and types are not sufficient to provide acceptable statistical power in the monitoring network. 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.
- **Northern-GIG collaboration:** The number of rivers selected for reference conditions monitoring in Norway can be reduced through collaboration in the N-GIG for at least some of the IC-types. This will have to be discussed further at the coming workshops in the N-GIG in April and September.
- **Glacier impacted rivers**: These river types has not been prioritized so far although glacier impacted rivers are assumed to be especially sensitive to climate changes. Therefore inclusion of glacier impacted rivers in the reference network should be considered.
- **Validation of the typology**: 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** For acidified rivers (indicated by an * in **Table 21, Appendix B**) suggested reference sites has to be validated against monitoring data.
- **Info about existing data and monitoring**: Info about existing data and acitivities (incl. water-flow registrations) should be compiled. Such information is important if further prioritizing of reference rivers is necessary.
- **Selection of sampling locations**: Within the suggested river-sections sampling localities has to be selected based on experience from existing studies, local knowledge and inspection of the rivers.

5. Coastal waters

5.1 Methods coastal waters

5.1.1 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 are for many areas a lack of biological and chemical data for high status sites, as the focus for monitoring programmes has historically been 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 programmes. 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 programmes.

5.1.2 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 programmes. In Norway, the main coastal monitoring programme which includes elements to be used in the WFD work is the Coastal Monitoring Programme, which was intiated in 1990 (Pedersen & Rygg 1990). This programme 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.

5.1.3 Chemical and biological datasets used for statistical testing and recommendations

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

5.1.4 Brief description of methods used for statistical testing

Statistical power is the the probability for detecting a significant deviation from the natural variation. Statistical power will vary between the quality elements and probably also between the different water types. So far we have used power analysis only on data for soft bottom fauna based on a data set from the Skagerrak ecoregion . The datasets have been collected within the Norwegian Coastal Monitoring Program.

We have used the software MONITOR 6.2 for calculation of number of sites and replicates necessary to discover trends in number of species between years for these data. The program is distributed for free at the Internett (http://nhsbig.inhs.uiuc.edu/wes/monitor_info.html).

5.2 Results coastal waters

5.2.1 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 (**Figure 11**).In addition straits with strong currents have been proposed as a separate water type for the two northernmost ecoregions.

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

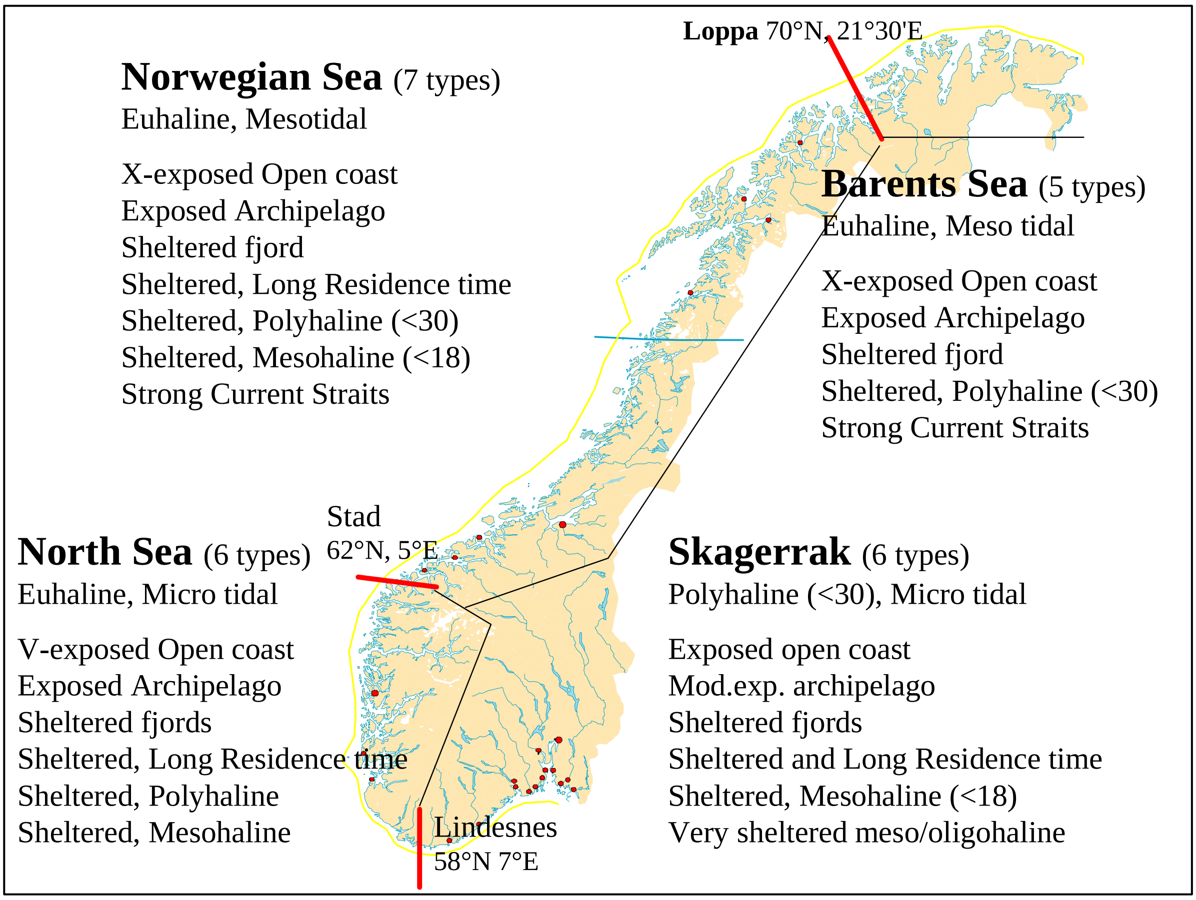

Figure 11. Proposed typology for the Norwegian coastal waters. 4 ecoregions and 23 different water types are suggested (Moy et al. 2003).

5.2.2 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 programmes. 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, littoral and sub-littoral macroalgal assemblages 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 in time and space. 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.

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, and also to supply and verify new data that are collected.

A new programme for monitoring of marine biodiversity along the Norwegian coast has been proposed, and several of the biological elements to be used in this programme are similar to elements to be utilised in the WFD work. A high degree of co-ordination is therefore important and will benefit both programmes. There is also an initiative for establishment of new marine protected areas in Norway. The monitoring of reference sites thus should preferably seek to establish study and monitoring sites within these areas.

The proposed areas for the national programme for monitoring of marine biodiversity in Norway (Nygaard et al. 2004) are shown in **Figure 12**.

In the designing of this programme, the areas proposed for marine conservation (**Figure 13**) were also taken into consideration, and where possible, overlapping areas were attained.

In addition to these two Norwegian initiatives, there is a proposal for a European network of sites for large-scale, long-term marine biodiversity research in Europe (**Figure 14**). This is highly relevant to the design of the monitoring program for Norwegian reference sites for the WFD.

Since all these marine biological monitoring initiatives are related and selection of sites are partly overlapping, the total cost of running the programmes can be significantly reduced. Possibilities of merging some of these programmes should also be considered, at least to some extent.

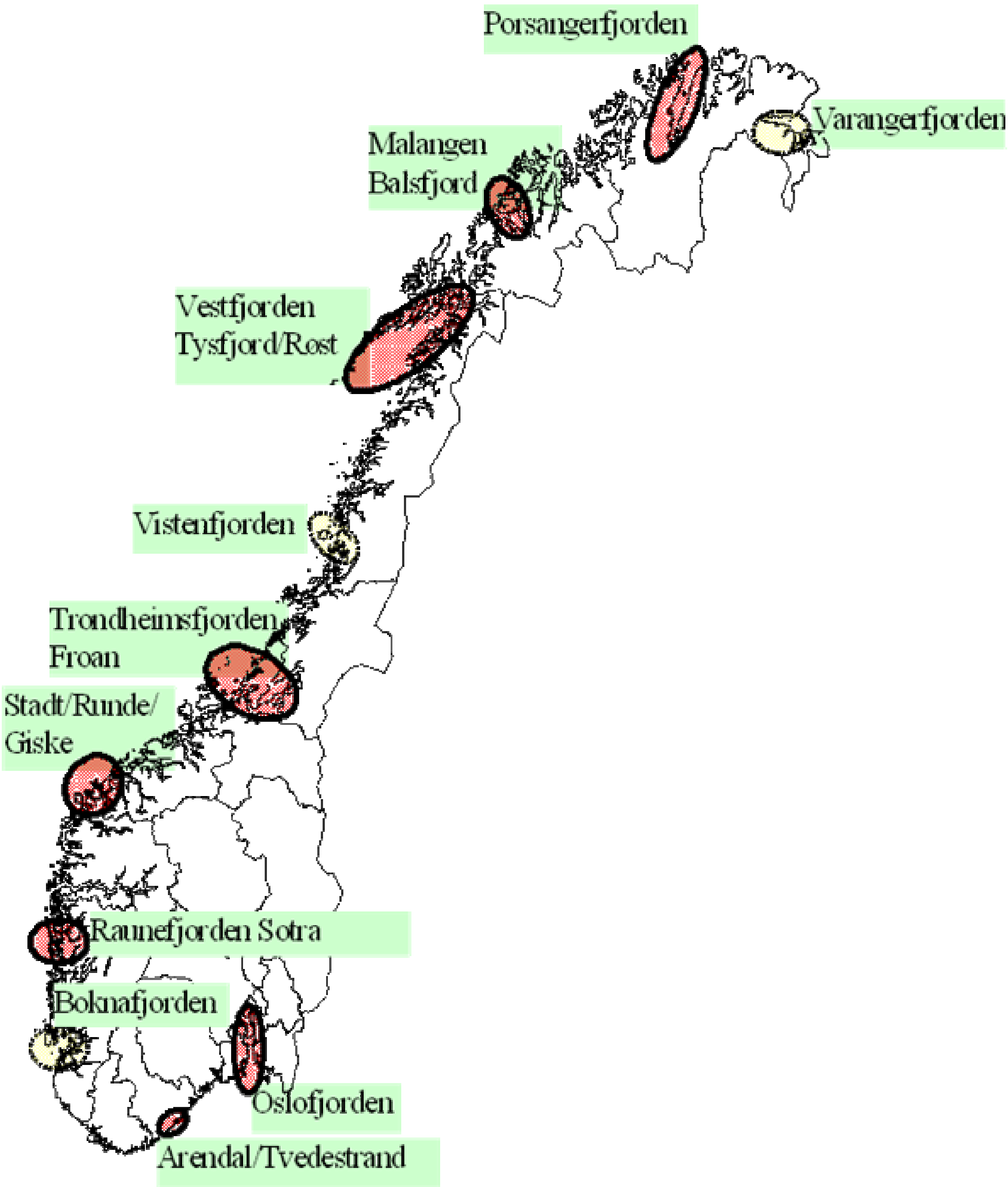

Figure 12. Proposed areas for monitoring of marine biodiversity in the Norwegian coastal zone. Red areas: main areas; Yellow areas: alternative areas (Nygaard et al. 2004).

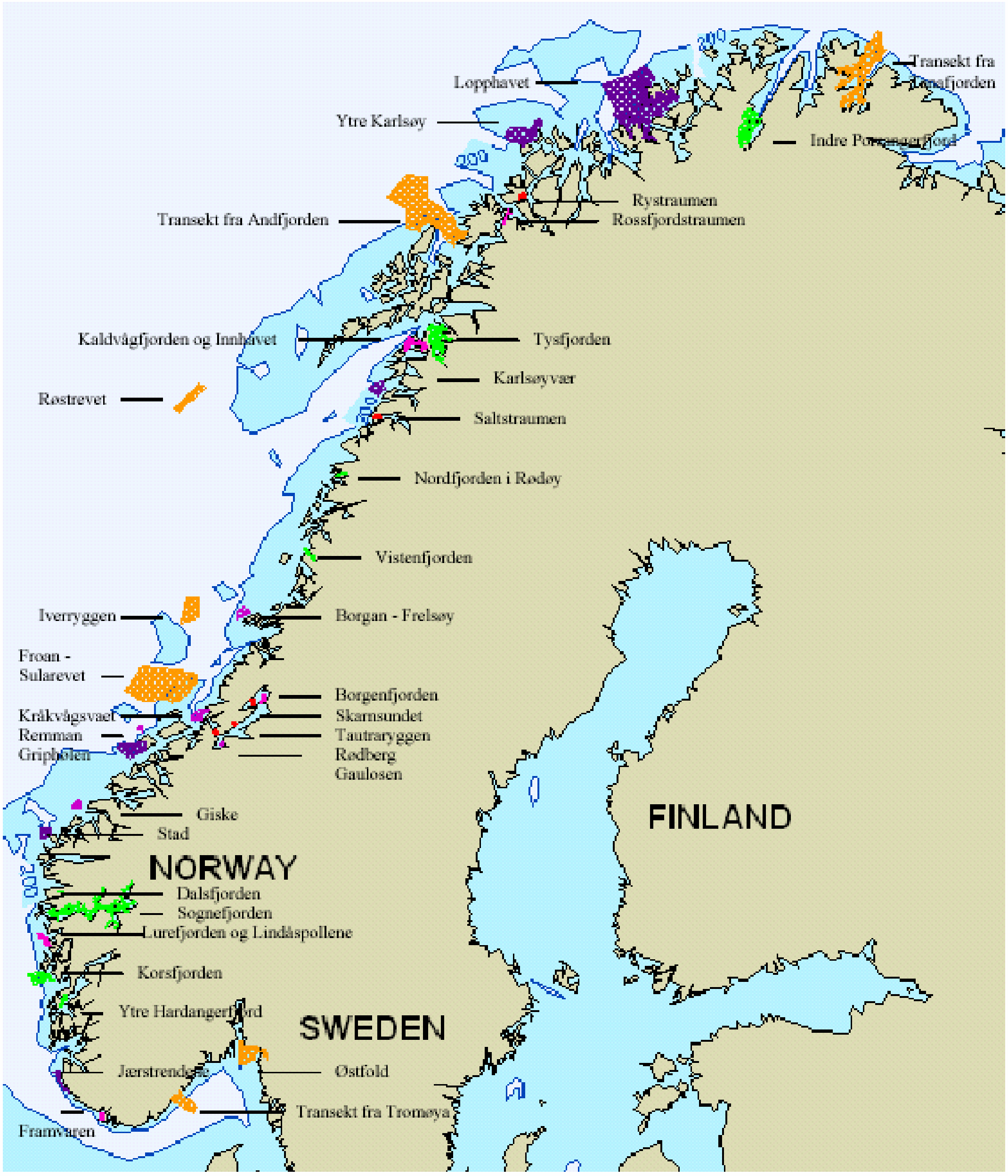

Figure 13. Proposal for marine protected areas in Norway (Skjoldal et al. 2003). In the map six different categories of areas are indicated. 1. Polls (light pink), 2. sound with strong current (red), 3. Special shallow areas (pink), 4. Fjords (green), 5. Open coastal areas (bluish pink), 6. Transects coast-open ocean (orange). The 200 m depth contour is also given.

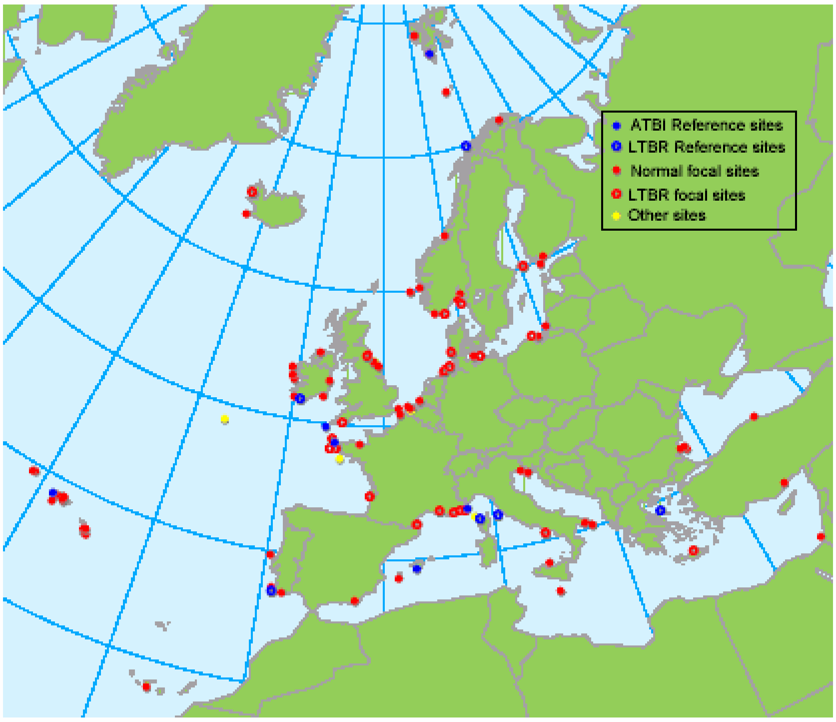

Figure 14. From the BIOMARE-programme: proposed European marine biodiversity reference sites. ATBI = All Taxon Biodiversity Inventory, LBTR= Long-Term Biodiversity Research. Blue sites have low anthropogenic influence. Red sites are suitable for effect studies of low level anthropogenic influence. (From Warwick et al. 2003).

5.2.3 Statistical testing and recommendations of number of sites per type

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 the number of species in soft bottom fauna, based on a limited data set from ecoregion Skagerrak. The data are from a 5 year period and the analysis is performed for 1, 2, 3, 5 and 10% annual decrease or increase in species density. After 5 years at the 5% level the decrease or increase in number of species will be 22.6% and 27.6%, respectively. At the 10% level the change over a 5 year period will be substantial, i.e. 41% and 61%, respectively. The results are shown in **Table 13**. The power to detect trends drops significantly when increasing the number of sites from 1 to 2, because the trend analysis have to be detected for 2 sites rather that at one. At one site spatial variation is minimal, however, when extending to 2 sites the spatial variance increases. Expanding to 3 or more sites the number of samples increases and the power increases as the spatial variance is accounted for.

Table 13. The probability of finding a decrease or increase (power) in number of species per 0.1 m^2 with varying number of sampling sites and replicate samples on each site. Data are based on a 5 year sampling periode.

	One site 1)			*Two sites* 2)			*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 programme; 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. In a monitoring design based on 4 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 (at least 24 samples).

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.

Similar approach should be adapted for the other quality elements ie. using preferably 4 or more sites as the best approach for describing a reference condition, which will enable estimation of type-specific natural variation.

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 of trends. To avoid misclassifications, a minimum number of sites are needed to display the acceptable natural variation for the water type.

5.2.4 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 clarify the possible use of already existing data from the many investigations already performed or still running in Norway. If no relevant and good quality data is 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. This will give the 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.

5.2.5 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 inhabiting 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 can be a good indicator of problems related to eutrophication. Phytoplankton is also important to monitor with regard to assessing the potential toxic accumulation in sea shells and dense algal blooms, which can be a nuisance for fish farming activities and a problem for survival of marine organisms in general.

In Norway sea grass has a very patchy distribution making the sea grass biotope less suited to monitor for regional assessments. Hard substrate invertebrate fauna is widely distributed, but has been monitored for a much shorter time compared to soft-bottom fauna, and assessment criteria needs further development . The important elements to be used under the WFD in Norway will probably be phytoplankton, benthic macroalgae and benthic invertebrates in soft-sediments (**Table 14**), and to a lesser extent hard substrate invertebrate fauna. These four elements and their interactions to each other are significant in holistic assessments of the Norwegian coastal ecology

Table 14. 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 **Table 15** together with the recommended sampling frequency and sampling season for Norwegian coastal waters. The recommendations also include minimum criteria for monitoring of marine biodiversity in Norway and for a large-scale, long-term marine biodiversity research in Europe and monitoring of marine conservation areas.

Table 15. Recommended elements, parameters, sampling frequency and sampling seasons for coastal waters (in blue). Benthic hard bottom fauna are optional (in yellow) as macrophytes cover the same substrate in the euphotic zone and are traditionally used as indicators on ecological status of an area.

Quality elements	Recommended minimum sampling frequency	Minimal sampling frequency based on WFD, Vedlegg V. NOT recommended! *
Biological quality elements		
Phytoplankton Taxonomic composition Biomass (chlorophyll and bio-volume) Diversity	**Annually** 20/year (Biweekly in growth season)	**Every 6 months** 2/year (Biweekly in growth season)
Macrophytes Taxonomic composition % Cover Lower growth limit Diversity	**Annually** 1/year (Summer)	**Every 3 years** 1/year (Summer)
Benthic fauna (hardbottom) (Optional) Taxonomic composition % Cover Diversity	**Annually** 1/year (Summer)	**Every 3 years** 1/year (Summer)
Benthic soft bottom invertebrates Taxonomic composition Abundance, Biomass Diversity	**Annually** 1/year (Spring)	**Every 3 years** 1/year (Spring)
Physico-chemical quality elements	**Annually**	**Every 3 years**
Tot-P (+ PO4 in bottom waters)	20/year (Biweekly in growth season)	20/year (Biweekly in growth season)
Tot-N and (NO3+NO2)	20/year (Biweekly in growth season)	20/year (Biweekly in growth season)
SiO3	20/year (Biweekly in growth season)	20/year (Biweekly in growth season)
Secchi depth	20/year (Biweekly in growth season)	20/year (Biweekly in growth season)
Temperature	20/year (Biweekly in growth season)	20/year (Biweekly in growth season)
Oxygen	20/year (Biweekly in growth season)	20/year (Biweekly in growth season)
TOC	20/year (Biweekly in growth season)	20/year (Biweekly in growth season)
Salinity	20/year (Biweekly in growth season)	20/year (Biweekly in growth season)
Hydro-morphological quality elements	**Annually**	**Every 6 years**
Water bodies movement & transport	Similar as for Physio-chemical quality elements as all calculations are based on these	Similar as for Physio-chemical quality elements as all calculations are based on these

* Not recommended, since limited or no information exists for both spatial- and temporal variance of the quality elements. However, subsequent to the establishment of these parameters one can re-evaluate the further design of the reference monitoring programme for coastal areas.

5.2.6 Selection of reference sites

Table 16 gives a summary of the areas suggested for use within the different programmes 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 programmes. **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 needs to be known, i.e. there is a need for quantitative data and to express statistical properties like mean number of species and the variance around the mean (like confidence limits).

Table 16. 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, and it is necessary to define its reference conditions. Data from the Swedish West Coast may be applied to describe reference conditions. This will be investigated further.

To obtain these variables a minimum number of reference sites is needed within each water type (Chap. 5.2.3). In particular during the initial testing for differences within and between water types.

The suggested marine reference areas for use in the WFD are shown in **Figure 15**. In the planning for suitable reference areas are several factors taken into consideration. These are mainly based on knowledge of the biological communities present and their status regarding possible effects from human disturbance. A separate project is currently identifying areas at risk of not reaching good status or reference status (SFT), but data from that project is currently not available.

In addition it is important to make use of existing data that is available and suitable as reference data in the WFD work. Some of the proposed areas may for example be impacted by biological processes like kelp grazing by sea urchins (like less exposed areas from Helgeland to Finnmark), and it may be difficult to find unaffected macroalgae communities in those areas. The invertebrate fauna in several soft-sediment areas along the coast are affected by bottom-trawling. Identification and mapping of these areas will be necessary before final reference sites can be determined.

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. Within each habitat (or type) it is necessary to sample at least 4 sites and take replicate samples within each site for most of the biological elements. There will be combinations of water types and biological elements that will have similar reference conditions and thereby allow a reduction of the number of samples. So far the marine data material has not been analyzed in this respect within this project. The amount of sample reduction can therefore not be quantified until further analyses have been done.

At present the number of data sets needed to describe reference conditions for the whole coast is limited. 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 surveys. In the short term, expert judgement will be employed 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 Programme and several local monitoring programmes can be used 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 (Table 16, Figure 15) are somewhat preliminary since they mainly are based on expert judgement. Precise decisions for final location of sampling sites will be taken when the examination of already available data is completed, and potentially more comprehensive local information is evaluated.

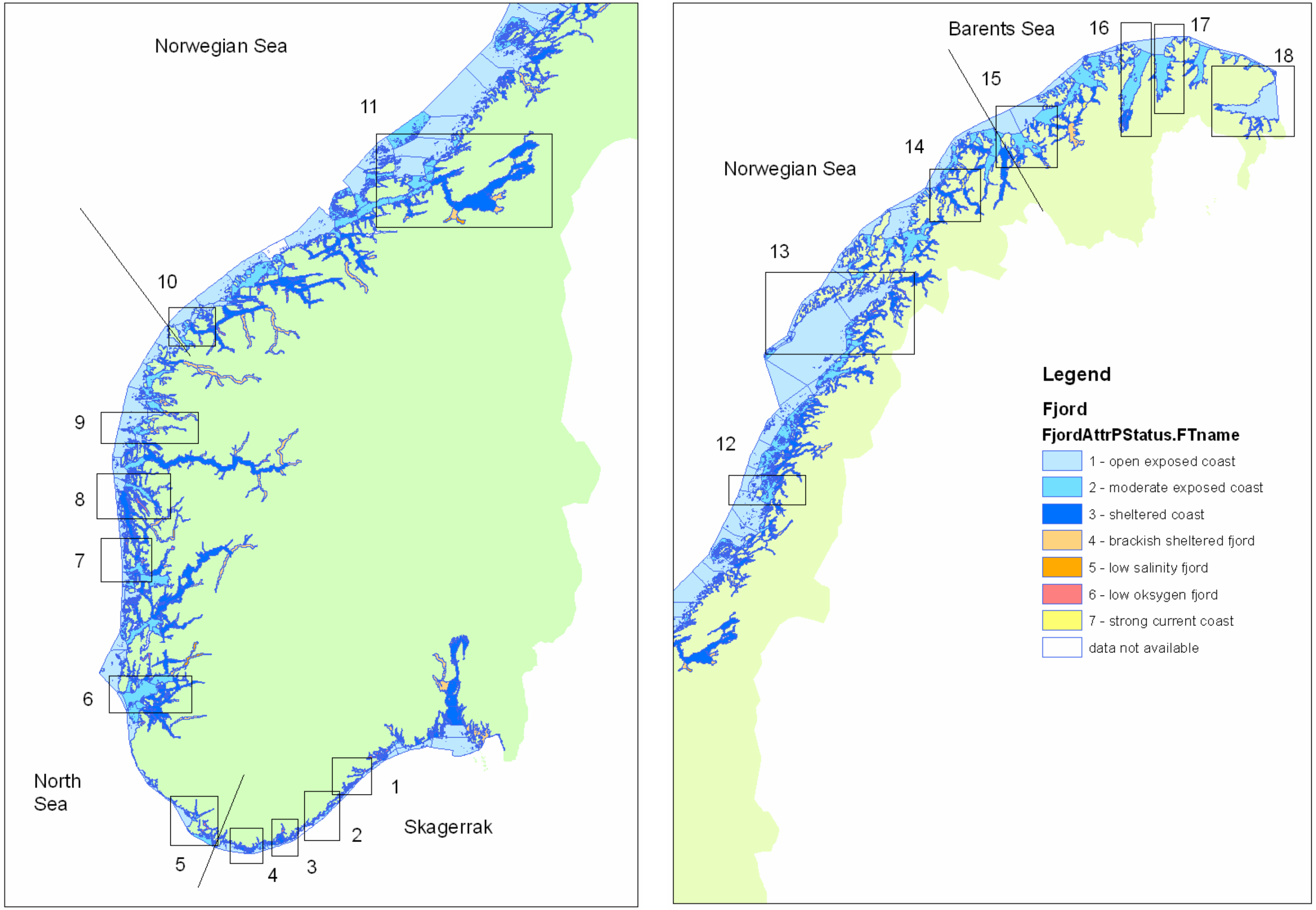

Figure 15. Proposed reference areas (18 areas) for coastal waters related to WFD implementation. These areas will be used to establish reference data for the biological quality elements phytoplankton, macroalgae and soft-sediment benthic invertebrates to confirm or refute the 23 water types proposed for Norwegian coastal waters (Moy et al. 2003). Based on these results, the number of reference areas for future WFD monitoring may be reduced (or increased).

To minimize the potential cost of such a programme, we made a reduction in the number of water types included (**Table 17**). The excluded water types are "Strong Currents" and "Sheltered Long Residence Time". Excluding these types can be justified since their reference conditions are rather site-specific, strongly depending on the local physical and hydrographical conditions. Hence no general type-specific reference conditions can be described.

The water types "Sheltered Polyhaline" and "Sheltered Fjords" are to some extent similar and might overlap in biological characteristics, hence they are combined in the programme. The risk of combining the "Types" is the potential higher variance for the different biological quality elements among sites.

Table 17. Excluded Water Types in the reference network design.

Ecoregions	Original no. of Water types (Moy et al 2003)	Excluded Types	Joined types	No. of Water types after reduction
Barents Sea	5	• Strong Currents	• Sheltered Polyhaline + Sheltered Fjords	3
Norwegian Sea	7	• Strong Currents • Sheltered Long Residence Time	• Sheltered Polyhaline + Sheltered Fjords	4
North Sea	6	• Sheltered Long Residence Time	• Sheltered Polyhaline + Sheltered Fjords	4
Skagerrak	5	• Sheltered Long Residence Time		4

Based on **Figure 15** the number of sampling sites for each biological quality element is listed in **Table 18**. The minimum ambition level is not sufficient to quantify the natural variation within individual transects, nor among types and ecoregions. This is a substantial limitation in the minimum program. The moderate ambition level, with 4 replicates within each transect, makes it possible to estimate significant differences between transects, hence to define precisely the type and ecoregion to which each transect belong. This is not possible at the minimum ambition level design. **On this background we recommend a programme at the Moderate Ambition level. After establishing the reference condition however, a minimum ambition level programme can be implemented**.

Table 18. Number of sites/samples at a high and low ambition level within the 4 ecoregions along the Norwegian coast.

Ecoregions	Reduced no. of water types (Table 17)	Optimal no. of sites in each type	No. of areas within each ecoregion (Figure 15)	No. of sampling sites **Moderate ambition level**	No.of sampling sites **Minimum ambition level**
Barents-sea	3	4	4	48	12
Norwegian Sea	4	4	5	80	20
North Sea	4	4	5	80	20
Skagerak	4	4	4	64	16
∑	15	32	18	272	68

5.2.7 Cost estimate coastal waters

The cost of surveying 1 site including all biological quality elements costs NOK 343 000 (**Table 19**). That implies an initial cost for establishing a reference network of 18 areas, each including a reduced number of reference water types (**Table 18**) sums up to 93 mill NOK pr. year. 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 size of a possible reduction in the budget cannot be given at present.

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.

Table 19. Estimated annual costs for 1 site and for all sites/samples at High and Low ambition levels. See above in text for the different reductions and limitations.

Quality Element	Frequency Sampling / year	Cost of each quality element (1000NOK)	Total no. of samples all types	Total no. of samples all types	Estimated Cost (1000NOK)	Estimated Cost (1000NOK)
		1 site	MODERATE ambition	LOW ambition	MODERATE ambition	LOW ambition
Phytoplankton	20	80	272	68	21,760	5,440
Macroalgae	1	100	272	68	27,200	6,800
Soft bottom fauna	1	63	272	68	17,140	4,280
Hydrography, nutrients and hydromorphology	22	100	272	68	27,200	6,800
Σ		343			93,300	23,320

6. 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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Appendix A. Selected reference lakes

Table 20. Selected reference lakes. Shades lakes belong to lake types which are not prioritized. The list contains 122 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. The list of reference lakes should be extended after further investigation of the output from the Characterisation project. This is necessary to cover the need for sites given in **Table 7**.

Geological lake type	Watershed no.	NVE No.	County	Name	MS_CD	Ecoregion, altitude, size
					water body id	
Very low alk., clear						
	002.LE	126	Hedmark	Atnsjøen	002126L	Ø2S
	104.D6Z	34660	Oppland	Svartdalsvatnet	10434660L	Ø1F
	002.DJCB	233	Oppland	Mjogsjøen	002233L	Ø1F
	002.DHEB	29185	Oppland	Nedre Søvertjørni	00229185L	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
	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
	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
	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						
	120.2E	2524	Sør-Trøndelag	Austvatnet	1202524L	M1S
Low alk., clear						
	310.5A	33258	Hedmark	Store Gunnarsjø	31033258L	Ø1S
	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
		965	Sør-Trøndelag	Songsjøen		M1S
	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
	002.G6D5	238	Hedmark	Eidsmangen	002238L	Ø1S
	313.C	353	Hedmark	Skjervangen	313353L	Ø2L
	002.JBB11	162	Hedmark	Osensjøen	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 i Odal	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

Possible additional lakes where type data is missing

NVE no	*Name*	*Comment*
272	Øvre Heimdalsvatn	Large research activity. Long time-series exist
	Bessvatn	Clearwater lake in the Sjoa catchment, which has been selected as a reference river

Appendix B. Potential reference rivers

Table 21. Potential reference sites for Norwegian rivers with based on the preliminary list of reference-rivers in Lyche Solheim et al. (2003). The water-body code is identical with the MS-code used in the Characterisation project (NVE per February 2005). One water-body (river site) may constitute of one or several small watercourses of lower orders. River types not included among common Norwegian river types in Lyche Solheim & Schartau (2004) are indicated and described in the foot-notes. Eco-regions indicated by: Ø: Eastern, V: Western, M: Central, N: Northern, coastal parts, F: Northern, inland parts. River size indicated by: 0: <10 km^2, 1: 10-1000 km^2, 2: >1000 km^2. Altitude regions indicated by: L: Lowland, S: Boreal, H: Highland. Bold types: Highly prioritized river types (see main text). The IC-types are originally restricted to Eastern, Western and Central eco-regions, whereas corresponding types in Northern Norway are indicated in italic letters. The water chemistry is indicated by a two-digit number, the first digit indicates clear (1), humic (2) or glacier (3) river, the second digit indicates very low alkalinity (1), low alkalinity (2) or moderate alkalinity (3) river. The IC-types R-N2, R-N3, R-N5, R-N7 and R-N9 have 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 Characterisation project. * Uncertain Ecological status due to acidification of the area – need a more thorough check. Rivers in yellow are included in the Riverine Inputs and Direct Discharges monitoring programme (RID).

Watercourse	Watercourse of lower order	Water-body	Ecoregion Size Altitude	Chem-type	IC type	Norw type
Haldenvassdraget	**Hafsteinelva** **Hemneselva** **Hølandselva**	**001003610R**	Ø0S	**22**	**R-N9**	**10**[1]
Glomma/Osa	**Nordre Osa** **Ossjøen**	**002029158R**	Ø0S	**22**		**10**[1]
Glomma/Atna	**Atna**	**002040087R**	**Ø1S**	**12**	**R-N5**	**9**
	Atna	**002062518R**	**Ø0S**	**12**		**9**[1]
	Atna	**002062523R**	**Ø0F**	**11**		**15**[1]
Lågen/Vorma/Sjoa	**Nedre Sjodalsvt** **Sjoa**	**002092768R**	**Ø0S**	**12**		**9**[1]
	Sjoa	**002092058R**	**Ø0S**	**12**		**9**[1]
	Sjoa	**002092443R**	**Ø0F**	**13**		**15**[1]
Sandvikselva	**Lomma**	**008000106R**	**Ø0S**	**22**		**10**[1]
Begna	**Dramselva**	**012073035R**	**Ø1L**	**22**	**R-N3**	**2**
	Begna	**012062674R**	Ø2S	**12**		**13**
	Sperillen	**012042633R**	Ø0S	**22**		**10**[1]
Oselvvassdraget		085xxxxxxR	V??		?	?
Eidfjordvassdraget/ Veig	**Veig**	**050003962R**	**V0F**	**11**		**15**[1]
Vossovassdraget*	**Raundalselvi**	**062001026R**	**V1S**	**11**	**(R-N5)**	**8**
	Raundalselvi **Kleivelvi**	**062001019R**	**V0F**			**15**[1]
Nausta*	Nausta	069000896R	V??	?	?	?
Gaularvassdr*	Gaula Hestadfjorden	083001370R	V??	11	?	?
Oldenvassdraget	Oldenvassdraget **Oldenvatnet**	088000001R	V??	12	?	?
Strynevassdraget	Hjelledøla Langvatnet Strynevatnet Videdøla	**088xxxxxxR**	**V?S**	**11**	**?**	**8**

Rauma	Rauma	103003329R	V2S	11		8[2]
	Rauma	103001937R	V0F	11		15[1]
	Lesjaskogvatnet Rauma	103001958R	V0F	11		15[1]
Driva	Driva	109006186R	M2S	12		13
Stjørdals- vassdraget	Austre Tverrsona	124001963R	M0S	12		9[1]
	Feren	124000449R	M0S	12		9[1]
	Forra	124000258R	M0S	12		9[1]
	Sona Vestr+Austre Sonvatnet	124002877R	M0S	12		9[1]
	Forra	124004101R	M1S	22	R-N9	10
Namsenvassdraget	Luru	139011896R	M1L	12	R-N2	1
	Namsen	139000052R	M0L	12		1[1]
	Namsen	139041036R	M2L	12		6
	Sørvatnet (St Namsvatnet)	 139049847R 139049849R	M0S	 12 12		9[1]
	Otersjøen Sandøla	139011251R	M1S	12 12	R-N5	9
	Alma	139016326R	M1S	12	R-N5	9
	Luru	139007422R	M1S	12	R-N5	9
	Namsen	139040693R	M2S	12		13
	Namsen	139040802R	M2S	12		13
	Alma	139007418R	M0F	12		16[1]
	Luru	139007416R	M0F	12		16[1]
Vefsna	Austre Tiplingen Vefsna	151018702R	M1S	12	R-N5	9
	Vefsna	151018686R	M1S	13		11
	Vefsna	151011728R	M2S	13		14
	Vefsna	151018304R	M0F	13		18[1]
Beiarelva	Beiarelva Tverråga	161001842R	M0F	13		18[1]
Saltdalsvassdraget	Lønselva	163005240R	N1S	12	*R-N5*	9
	Lønselva	163001777R	N0F	12		16[1]
Skjomavassdraget	 Nordelva	173003484R	N1S	32		New[3]
	 Nordelva Storvatnet (Cunojavri)	173001442R	N1F	32		17
Målselvvassdraget	Målselvvassdraget	196014747R	F2L	13		7
	Rostaelva	196023642R	F1S	13		11
	Rostaelva	196024001R	F1S	13		11
	Rostaelva	196024614R	F1F	12	*R-N7*	16
	Rås'tajav'ri	196023643R	F1F	23		New[4]
Reisaelvvassdraget	Njallajåkka Reisavassdraget	208000509R	F1S	22	*R-N9*	10
	Njallajåkka Reisavassdraget	208000512R	F1S	22	*R-N9*	10
	Reisavassdraget	208003141R	F0S	22		10[1]
	Reisavassdraget	208003449R	F2S	23		12[2]
	Reisavassdraget	208000523R	F0F	12		16[1]
Altavassdraget	Kautokeinoelva	212000004R	F1S	22	*R-N9*	10
	No name	212000064R	F1S	22	*R-N9*	10
	Bajit Vuoccetjav'ri Cabardasjåkka Duol'bajav'ri Guov'dagãinãdno Jumesjav'ri Kautokeinoelva Vuoccetjåkka Vuolit Vuoccetjav'ri *No name*	212002424R	F??		?	?
	Guov'dagãinãdno Kautokeinoelva	212005912R 212005912R	F2S	12		13
	Cabardasjåkka	212013922R	F1S	22	*R-N9*	10
	Altavassdraget Duol'bajav'ri Guov'dagãinãdno	212013934R	F2S	22		10[2]

	Lup'pujåkka					
Lakselvvassdraget	Lâvdnjajåkka	224003317R	F1L	?		?
	Lâvdnjajåkka	**224001006R**	**F0S**	**23**		**12**[1]
	Luos'tejohka	**224001023R**	**F0S**	**22**		**10**[1]
	Luos'tejåkka	**224002291R**	**F1S**	**22**	***R-N9***	**10**
Børselvvassdraget	**Bis'sujåkka**	**225001061R**	**F0S**	**23**		**12**[1]
	Bis'sujåkka	**225002371R**	**F1S**	**23**		**12**
	Bis'sujåkka	**225002541R**	**F1S**	**23**		**12**
	Viek'sajåkka	**225002357R**	**F1S**	**23**		**12**
	Månsjåkka	225000987R	F1F	22		New[5]
	Bis'sujåkka	225000991R	F1F	13		18
Tana	**Karasjåkka**	**234023494R**	**F0S**	**22**		**10**[1]
	Dãdno	**234006274R**	**F2S**	**23**		**12**[2]
	Karasjåkka	**234013422R**	**F0S**	**23**		**12**[1]
	Dãdno Gamehisjåkka Anarjåkka	**234023416R**	**F0S**	**23**		**12**[1]
	Iesjåkka Suossjav'ri	**234014301R**	**F0F**	**12**		**16**[1]
Vesterelv-vassdraget	**Syltefjordelva**	**237001837R**	**F1L**	**12**	***R-N2***	**1**
	Syltefjordelva	**237001841R**	**F1S**	**12**	***R-N5***	**9**
	Oardujav'ri Stuorra Oar'do Syltefjordelva	**237000912R**	**F1F**	**12**	***R-N7***	**16**
	Rav'dul Syltefjordelva	237000896R	F0F	23		New[4]
Sandfjord-vassdraget	**Sandfjordelva**	**238001744R**	**F1L**	**12**	***R-N2***	**1**
	Sandfjordelva	**238000990R**	**F0F**	**12**		**16**[1]
	Sandfjordelva	**238001219R**	**F1F**	**12**	***R-N7***	**16**
Pasvikelva	**Baccavãjåkka**	**246000003R**	**F0L**	**22**		**2**[1]
Sudajåkka/Karpelva	**Sudajåkka**	**247000176R**	**F0S**	**22**		**10**[1]
	Sudajåkka	**347000301R**	**F1S**	**22**	***R-N9***	**10**

[1] *Very small river (<10 km^2)*
[2] *Large river (>1000 km^2)*
[3] *Boreal, glacier impacted river*
[4] *Highland, siliceous, moderate alkalinity, organic (mixed)*
[5] *Highland, siliceous, low alkalinity, organic*

Table 22. Additional rivers, from which potential reference-sites may be selected. The reference status of these rivers has to be checked by applying the results from the Characterisation Projects. See

Table 21 for further explanations.

Watercourse	Watercourse of lower order	Water-body (MS-code or Regine no)	Ecoregion Size Altitude	Water-type	IC type	Norw type
Glomma/Håelva	**Håelva**	002.QZ	**Ø??**	**22**	**R-N9**	**10**
Glomma/Mistra			Ø??			
Glomma/Tunna			Ø??			
Nordmarksvassdr	Second order rivers upstream Lake Maridalsvatn		Ø?S			
Lågen/Vorma	Vismunda	002.DDA2				
Lågen/Otta	**Frøysa**	**002103XXXR**	**Ø?F**	**12?**	**R-N7**	**16?**
	Måråi	**002103XXXR**	**Ø?F**	**12?**	**R-N7**	**16?**
	Vulu	**002103XXXR**	**Ø?F**	**12?**	**R-N7**	**16?**
	Tora	**002103XXXR**	**Ø?F**	**12?**	**R-N7**	**16?**
	Ostri	002103400R	Ø?F	33		17
	Åfotgrovi	002103XXXR	Ø?F	33		17
	Tundra	002103XXXR	Ø?F	33		17
	Skjøli	002103XXXR	Ø?F	33		17
	Bøvra	002110(973)R	Ø?F	33		17
Lågen/Frya	Frya	002.DF3Z				

Trysilvassdraget	**Røa**	311.DB1Z	**Ø?S**	**22?**	**R-N9?**	**10?**
	Mugga	311.J8Z	**Ø?S**	**22**	**R-N9**	**10**
Skiensvassdraget	Skiensvassdr (SW lower parts)		**Ø?S**	?	?	?
	Skiensvassdr (upper parts)		**Ø?S**	?	?	?
Tyssevassdraget		060.6Z	V??	?	?	?
Etne		060xxxxxxR	V??	?	?	?
Ekso		063xxxxxxR	V??	?	?	?
Yndesdalsvassdr		067.6Z	V??	?	?	?
Aurlandsvassdraget			V??	?	?	?
Lærdalselva	Kuvella	073xxxxxxxR	V??	?	?	?
	Others (second order rivers)?		V??	?	?	?
Ervikelven (Stadt)						
Bondalselva	*Bondalselva, central parts*	097.1Z	V?S	12	?	?
	Rognstøylsvatn, outlet	097.1Z	V?S	12	?	?
Visavassdraget	*Tverrelva, central parts*	104.2AZ	M?S	11	?	?
	Måsvatn, outlet	104.2AZ	M?S	11	?	?
Surna	Surna, upstream regulations	112xxxxxxR	M??	?	?	?
	Others (second order rivers)?		M??	?	?	?