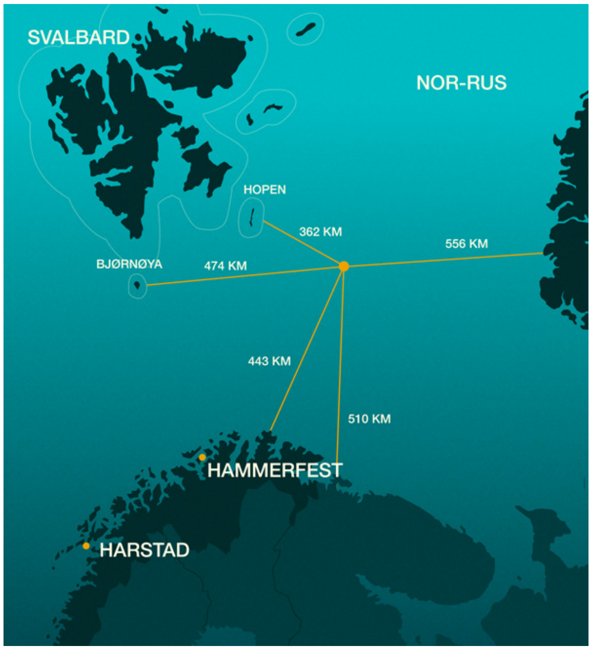
Miljørisiko og oljevernberedskap i Barentshavet sørøst

Barents Sea Exploration Collaboration (BaSEC) er et industrisamarbeid for å forberede leteoperasjoner i Barentshavet. Barentshavet har vært åpent for petroleumsaktivitet siden 1980, men industrien beveger seg nå inn i nye områder av dette havområdet. BaSECs siktemål er derfor å koordinere operatører og komme med anbefalinger om tiltak som kan danne grunnlag for sikker og effektiv letevirksomhet i Barentshavet. BaSEC har 17 medlemmer, alle operatører på norsk sokkel. BaSEC bygger sine rapporter på beste tilgjengelige kunnskap og på den brede erfaring disse 17 selskapene har fra operasjoner i Barentshavet, andre steder på norsk sokkel og i andre områder med tilsvarende forhold.

Sammendraget dekker tre rapporter om tre tema: miljørisiko, oljevernberedskap og status for oljevern i is. De tre rapportene er laget med utgangspunkt i blokk 7435/9 som inngår i lisens PL859. Rapportene ble utarbeidet i forkant av vårens tildelinger i 23. konsesjonsrunde. Lisensgruppen som nå har ansvaret for lisens PL859 vil utarbeide miljørisikoanalyser når de bestemmer seg for hvor og når man skal bore letebrønner i denne lisensen.

Blokk 7435/9 ligger midt i Barentshavet med stor avstand til land. Nærmeste landområde er Hopen som er 380 km unna, det er 440 km til fastlandet (Nordkapp) og ca. 500 km til Bjørnøya. Dette er en viktig forutsetning for de vurderingene som gjøres i miljørisikoanalysen. I tillegg er det viktig å merke seg de funn som er gjort i BaSECs rapport om «Fysisk miljø i Barentshavet sørøst», som ble offentliggjort tidligere i 2016. Videre har rapporten brukt en generell sannsynlighet for utblåsning på 0,014 % eller 1 gang per 7092 letebrønner. Det er forventet at denne risikoen vil være lavere ved senere analyser på grunn av reservoarenes lave trykk og lave temperatur.



Figur 1: Lokalisering av brønn for miljørisikoanalysen

Rapporten er laget av DNV GL og har anvendt best tilgjengelige data, slik som Seapop og SEATRACK for å kunne si noe om risikoen ved en eventuell oljeutblåsning. Anerkjente analyseverktøy som OSCAR for oljedriftsimulering er også brukt. Rapporten har også for første gang gjennomført en dynamisk simulering av olje i drift i forhold til den marginale issonen og vurdert sårbarheten til dyrelivet i området definert som polarfronten.

Hovedfunnene knyttet til miljørisiko ved en oljeutblåsning fra blokk 7435/9 kan oppsummeres med at:

- Oljen fra en utblåsning vil ikke nå land
- Så lenge aktiviteten foregår i henhold til myndighetenes krav om en 50 kilometers buffersone er det svært lite sannsynlig at oljen fra en eventuell utblåsning vil nå inn i iskantsonen
- En oljeutblåsning vil i hovedsak påvirke sjøfugl på åpent hav – det er mer enn 70 % sannsynlighet for ingen skade og inntil 30 % sannsynlighet for en skade hvor bestanden vil være gjenvunnet i løpet av 1-3 år
- Det er ikke funnet bestandseffekter på sjøpattedyr eller på fisk
- Eksisterende oljevernutstyr vil kunne benyttes med betydelig effekt

Hvor stor er sannsynligheten for en oljeutblåsning?

Selv om Barentshavet ligger langt mot nord, viser erfaring og kunnskapen om geologien i området at det ikke er mer komplisert å bore der enn andre steder på sokkelen. I Barentshavet er det ikke høyt trykk i reservoarene, i motsetning til enkelte steder i Nordsjøen og i Norskehavet. Det lave trykket innebærer at det er liten sannsynlighet for en ukontrollert utblåsning. En eventuell utblåsning vil derfor ha et begrenset skadepotensiale.

I denne rapporten har BaSEC likevel, basert på relevant historisk statistikk, brukt en generell frekvens risiko for oljeutblåsning tilsvarende 1 utblåsning for hver 7092 letebrønn. Dette tilsvarer en sannsynlighet for utblåsning på 0,014 prosent. Det antas at dette er en høyere risiko enn den man vil se i de forskjellige boremålene i de tildelte lisensene.

Siden 1969 er det boret om lag 1500 letebrønner totalt på norsk sokkel, hvorav ca. 130 brønner i Barentshavet.

Vil oljen kunne nå kysten?

Leteblokk 7435/9 i Barentshavet sørøst (en del av lisens PL859) ligger 380 km fra nærmeste landområde på Hopen og hele 440 km nord for fastlandet på Finnmarkskysten. Avstanden til den maritime grensen mellom Norge og Russland er 30 km. En eventuell oljeutblåsning ved leteboring i området vil derfor ikke nå kysten.

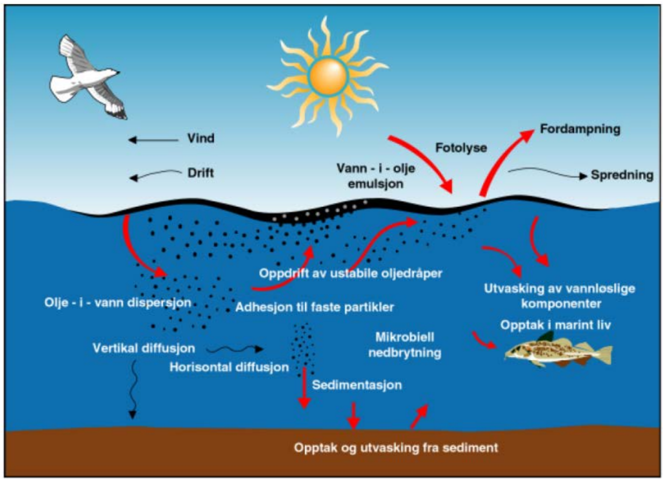
Skrugard-olje, som er oljetypen valgt for området ved blokk 7435/9, har en relativt kort levetid – 2 døgn – på sjøen ved mye vind og høye bølger, men kan holde seg en drøy uke på havoverflaten under rolige værforhold.

Fordampningen og nedblandingen ved en eventuell oljeutblåsning eller et eventuelt oljeutslipp, starter like etter oljen legger seg på havoverflaten. Da iverksette tre prosesser fra naturens side som alle bidrar til at oljeflaket brytes opp og forsvinner.

Første fase. De lette delene av oljen fordamper. Hvor fort det skjer, avhenger av værforhold og oljens konsistens. Forventet olje i Barentshavet sørøst kjennetegnes ved å være lett. Konsistensen gjør at fordampingen vil skje raskere der enn i de fleste andre havområder.

Andre fase. Oljen blandes ut med vann. Dette kan øke volumet på oljeflaket selv om konsentrasjonen av olje synker.

Tredje fase. Den viktigste prosessen er den naturlige oppløsningen av oljen. Oppløsningen skjer i hovedsak ved at vind og bølger brekker opp oljeflaket i små oljedråper. Jo større bølger og jo kraftigere vind, desto fortere brytes oljeflaket opp. Disse dråpene blandes så inn i vannet under havoverflaten. Ganske raskt synker da konsentrasjonen av giftige stoffer til under nivået som påvirker levende organismer. På det tidspunktet kan ikke lenger oljen skade livet i havet.



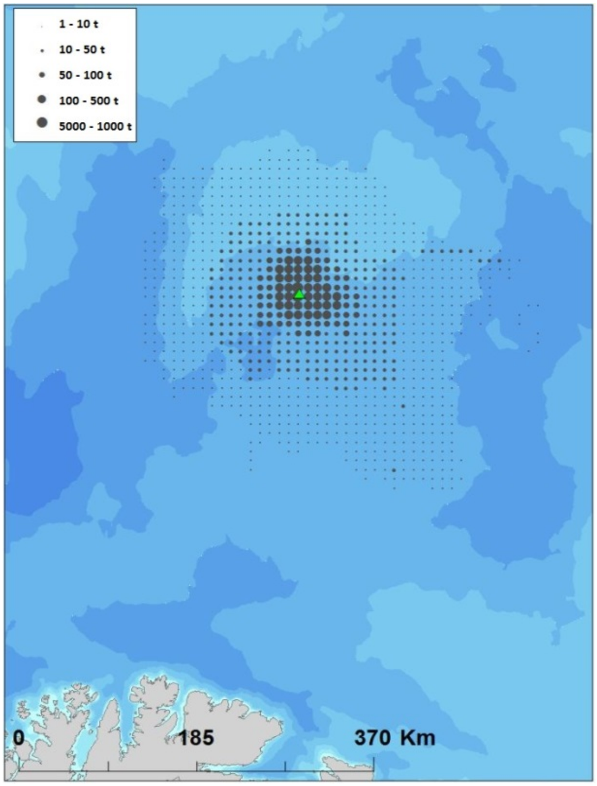
Figur 2: Naturlig nedbryting av olje på havoverflaten. Kilde: SINTEF

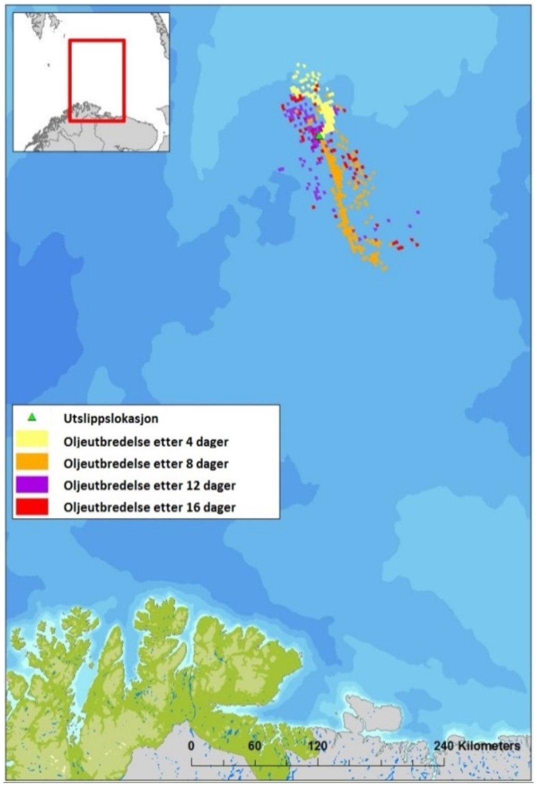
Antatt levetid på overflaten for olje i Barentshavet sørøst er fra to dager til en drøy uke. I tillegg til dette vil det være oljeverntiltak som tar opp olje fra havoverflaten og/eller øker nedbrytingen av oljen i vannet. Det er strenge krav til å være forberedt på slike situasjoner, og alle operasjoner i Barentshavet har og vil ha en god beredskap for oljevern.

Oljedriftsberegninger viser at oljen fra en utblåsning er forventet å bre seg inntil 100 km fra utslippspunktet, men at oljen i noen tilfeller kan drive så langt som 200-250 km på havet før den er fordampet og nedblandet i vannmassene. Jo lengre oljen kommer vekk fra utblåsningspunktet, jo mindre er konsentrasjonen av oljen og mulige miljøeffekter avtar i takt med reduksjon i konsentrasjon.

Figur 3 (på neste side) viser hvor oljemengdene fra en utblåsning i blokk 7435/9 i hovedsak kan havne. Et enkeltutslipp vil dekke et mye mindre område, men vil ikke gå utenfor det merkede området. Figuren er en simulering av hvor et stort antall oljeutslipp kan drifte under ulike historiske vind- og strømforhold.

Figur 4 (på neste side) viser hvordan et enkeltutslipp vil bevege seg over en 16-dagers periode. Dette er en tilfeldig utvalgt simulering.





Figur 4: Vektet oljemengde i tonn per 10x10km ved en overflateutblåsning

Figur 3: Utbredelse av olje på havoverflaten over en periode på 16 døgn i en tilfeldig valgt utblåsningssimulering

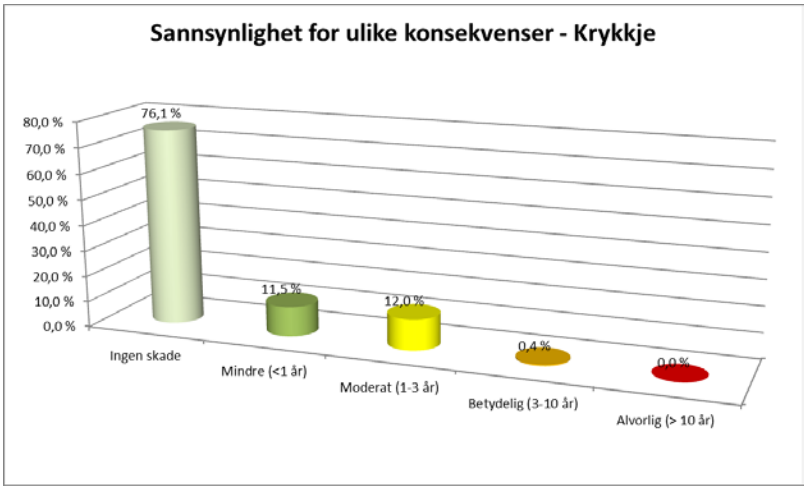
Vil oljen kunne nå iskanten?

Oljedriftsberegningene som er utført for blokk 7435/9 i lisens PL859 viser at det er svært lite sannsynlig at olje driver inn til en iskant som er mer enn 50 km unna. Beregningene viser en samvariasjon som gjør at selv om man forventer at olje kan drive 100 km så driver den som regel i samme retning som isen, dvs. når isen rykker sørover driver også oljen sørover og når isen trekker seg tilbake vil oljen drive nordover igjen.

Overgang fra åpent hav til islagt hav (iskanten) har variabel karakteristikk fra dag til dag, fra måned til måned og fra år til år. Forvaltningsplanen for Barentshavet og Lofoten benytter derfor en definisjon på iskanten som det området hvor mer enn 15 % av havflaten er dekket av sjøis i mer enn 30 % av dagene i april. Typisk ser man da på sannsynlighet basert på mange år med historiske isutbredelser (10-30 år med data). Blokk 7435/9 ligger cirka 150 km sør for det iskantområdet etter denne definisjonen. Regelverket tilsier at dersom iskanten kommer nærmere enn 50 km fra borelokasjonen skal en leteboringsoperasjon settes på vent inntil isen igjen er mer enn 50 km unna.

Hvordan vil en oljeutblåsning påvirke sjøfugl og sjøpattedyr på havet?

Analysene som er utført for blokk 7435/9 viser at det er sjøfugl som vil kunne bli mest berørt. Dette inkluderer arter som krykkje, lunde og polarlomvi. Selv om enkeltindivider vil kunne dø er det beregnet at det er over 70 % sannsynlighet for at en eventuell oljeutblåsning ikke vil medføre skade (mer enn 1 % tap) på sjøfuglbestandene i Barentshavet. Det er mindre enn 1 % sannsynlighet for å få en betydelig miljøskade, som vil medføre 3-10 års restitusjonstid for bestanden av krykkje i Barentshavet (se figur 6).



Figur 5: Sannsynlighet for effekt på krykkje

Beregningene er utført basert på data fra Seapop (seapop.no) som har utarbeidet kart som viser artenes utbredelse på åpent hav om sommeren, høsten og vinteren.

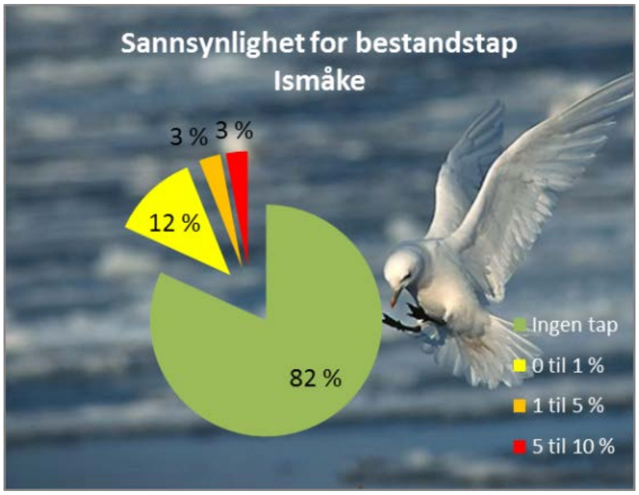
Generelt kan vi si at det er svært stor variasjon i hvilke konsekvenser en oljeutblåsning vil få for sjøfugl og sjøpattedyr avhengig av værforholdene når et utslipp skjer og hvor mye sjøfugl og sjøpattedyr det er i området. Konsekvensen vil også variere med hvor sårbare ulike individer er for olje, men også hvor sårbare ulike bestander er i forhold til en nedgang i populasjonen.

Et annet usikkerhetsmoment er Polarfronten – skillet mellom varmt atlantisk vann og kald arktisk vann og hvilke biologiske ressurser som finnes der. Datasettene er for grove til å fange opp større tettheter av fugl i polarfronten. Hvis man likevel analyserer en utblåsningseffekt på en hel bestand som skulle befinne seg i umiddelbar nærhet av utblåsningen, forventer vi at bestandstapet fremdeles er på under 10 %. Bestanden vil da i løpet av 1-3 år gjenvinne størrelsen. Dette er innenfor det som på norsk sokkel er en akseptabel risiko. Igjen er det viktig å huske på at sjansen for en utblåsning i seg selv er på 0,014 %.

Hvordan vil en oljeutblåsning påvirke dyrelivet i iskanten?

Borelokasjonen ligger et stykke unna iskanten, og det er beregnet en lav sannsynlighet for at olje vil berøre iskanten ved en eventuell oljeutblåsning. Det forventes derfor ikke at dyrelivet i iskanten vil bli vesentlig berørt. Oljen i denne delen av Barentshavet har relativt kort levetid (2 døgn) på sjøen ved mye vind og høye bølger. Den kan holde seg i en drøy uke på havoverflaten under rolige værforhold.

Beregninger utført for ismåke viser at selv i vinter- og vårsesongen, hvor iskanten er nærmest borelokasjonen, så er det ved en utblåsning mer enn 80 % sannsynlighet for at man ikke får konsekvenser på ismåkebestanden (se figur 7). Det er generelt lite spesifikke datasett tilgjengelig som viser utbredelsen av dyrelivet i iskantsonen. For å vurdere mulige konsekvenser på sjøfugl ble det derfor opparbeidet et datasett på utbredelse av ismåke, en høyarktisk art som har tilhold i isfylte farvann hele året. Datasettet er dynamisk og viser utbredelsen i områder med 20 til 50 % is.



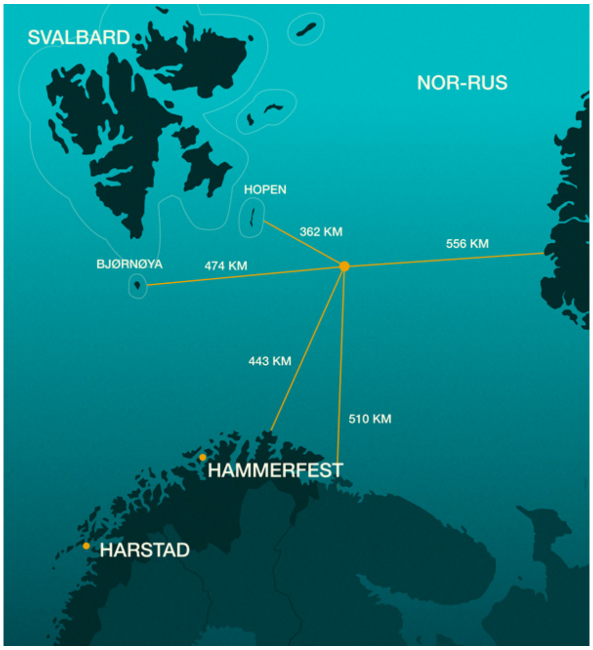
Figur 6: Sannsynlighet for bestandstap av ismåke

Dataene om ismåke baserer seg på GPS-logger-studier i SEATRACK. Dette er et helhetlig og langsiktig overvåkings- og kartleggingsprogram for norske sjøfugler. Datasettet kan også være relevant for andre arter i den marginale issonen slik som for eksempel sel.

Hvordan vil en oljeutblåsning påvirke dyrelivet i kyst- og strandsonen?

Risikoen for en utblåsning er på 0,014 %. I og med at borelokasjonen i blokk 7435/9 er mer enn 380 km fra nærmeste landområde på Hopen og mer enn 440 km fra Finnmarkskysten, så vil ikke olje fra en eventuell utblåsning leve så lenge på havoverflaten at den vil kunne nå land. Det vil derfor ikke være noen bestandseffekter på dyrelivet i kyst- og strandsonen.

Oljen i denne delen av Barentshavet har relativt kort levetid (2 døgn) på sjøen ved mye vind og høye bølger. Den kan holde seg en drøy uke på havoverflaten under rolige værforhold. Enkelte sjøfuglarter, som for eksempel lunde kan fly så langt som 100 km ut fra hekkekolonien for å finne mat. Individer av enkeltarter som er basert langs land forventes derfor i svært begrenset grad å bli påvirket av en utblåsning fra denne blokken.



Figur 7: Lokalisering av brønn for miljørisikoanalysen

Hvordan vil en oljeutblåsning påvirke fisk og livet i havet?

Ved en eventuell oljeutblåsning vil bølger føre til at noe av oljen naturlig blandes ned i vannsøylen. Det vil imidlertid være en rask fortynning i tid og rom i av de giftige oljekomponenter i vannsøylen som kan gi effekter på livet i havet. Det er først og fremst fiskeegg- og larver som er mest sensitive for oljepåvirkning. Det er ikke vist til særlig stor konsentrasjon av fiskeegg- og larver i området rundt borelokasjon 7435/9 og modellerte oljekonsentrasjoner i vannsøylen er lave. Det vil kunne være dødelighet av egg- og larver i nærområdet 20-30 km rundt en utblåsning, men dette forventes ikke å føre til målbare konsekvenser for fiskebestander i Barentshavet.

Det er i cirka 250 meters vanndyp på borelokasjonen og skulle en utblåsning skje på sjøbunnen og ikke på overflaten, forventes det allikevel at gass og reservoartrykk vil føre oljen raskt opp til overflaten for så å spres på samme måte som et overflateutslipp.

Hvilken effekt kan vi forvente av oljevernberedskap i dette området?

En oljevernberedskapsanalyse er utført for et utblåsningsscenario fra blokk 7435/9 i lisens PL859. Størst beregnet effekt har en kombinasjon av mekanisk opptak med lensesystemer og dispergering fra fly. En slik kombinasjon vil kunne redusere oljen på overflaten med inntil 75 % under optimale forhold i løpet av de første fem dagene. Av de vurderte teknikkene er det mekanisk opptak som viser størst potensiale i iskonsentrasjon opp til 30 %. Det vurderes imidlertid som svært lite sannsynlig at et eventuelt oljesøl vil nå iskanten.

På tross av lav sannsynlighet for oljepåslag i is, tar studien for seg ulike beredskapsteknikker både i åpent hav og i isfylte farvann. Den belyser hvilke teknikker som kan fungere best på en eventuell utblåsning i dette området. Dette omfatter både mekanisk opptak med både konvensjonelle og aktive lensesystemer, kjemisk dispergering både fra fly og fra fartøy, brenning og undervannsdispergering. I tillegg er det sett på et konsept for et fartøy som kan utføre flere typer oljeverntiltak i isfylte farvann opp til 30 % iskonsentrasjon.

Målet er at flest mulig av disse beredskapsteknikkene er tilgjengelige og kan benyttes basert på hvilke forhold det til enhver tid er rundt utslippet. Beredskapen vil være sammenlignbar med effektiviteten andre steder på norsk sokkel. Den viktigste forskjellen er at forskjellen i effekt mellom sommer og vinter er større enn på andre deler av sokkelen. Dette skyldes blant annet lysforhold.

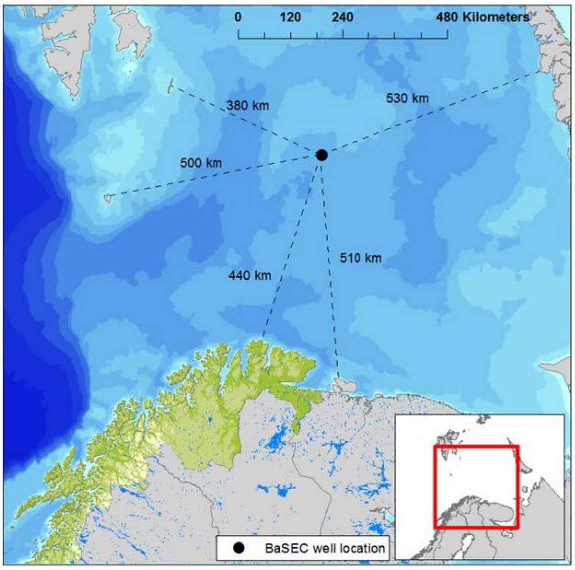
Flere øvelser har blitt utført i Finnmark vinteren 2015. En øvelse ble også gjennomført i iskanten senvinteren 2015. Øvelsene har gitt verdifull informasjon og erfaringer om norsk oljevernberedskap i kaldt klima og is, og underbygger de utførte beregninger. Øvelsen demonstrerte bl.a. at et vanlig NOFO-system kan settes ut og opereres etter dagens prosedyrer. Anti-is middel (glykol) kan benyttes på sentrale komponenter for å motvirke ising.

For isfrie farvann er eksisterende og tilgjengelige løsninger på norsk sokkel for oljedeteksjon dekkende, men datakommunikasjon kan være en begrensende faktor så langt nord. Tiltak for å forbedre digital kommunikasjon fra skip viser gode resultater, og digitale downlink-systemer fra fly fungerer også godt.

Dersom et oljeutslipp skulle drive inn i Russisk farvann er det etablert en overenskomst mellom Norge og Russland angående samarbeid om bekjempelse av oljeforurensning i Barentshavet. I medhold av avtalen er det utarbeidet en felles Norsk-Russisk beredskapsplan for oljevernaksjoner i Barentshavet. Planen regulerer samarbeid mellom myndigheter i de to landene når det gjelder aksjoner mot oljeutslipp, gjennomføring av øvelser og jevnlige møter.

Teknisk sammendrag av miljørisikoanalyse og oljevernberedskapsanalyse for letebrønn 7435/9 i Barentshavet sør-øst

Sannsynligheten for en oljeutblåsning fra en letebrønn i området er basert på historiske data fra SINTEF offshore blowout database og er beregnet til $1.41x10^{-4}$ per leteboring, som tilsvarer en utblåsning for hver 7092 letebrønn eller en risiko for utblåsning på 0,014 %. Selskapenes miljøakseptkriterier for ulik miljøskade ved leteboringsaktivitet er:



- 1 mindre miljøskade for hver 1000 leteboring
- 1 moderat miljøskade for hver 4000 leteboring
- 1 betydelig miljøskade for hver 10 000 leteboring
- 1 alvorlig miljøskade for hver 40 000 leteboring

Hvilket område vil bli berørt av en oljeutblåsning i blokk 7435/9?

Blokk 7435/9 ligger midt i Barentshavet med stor avstand til land. Nærmeste landområde er Hopen som er 380 km unna og det er 440 km til fastlandet (Nordkapp) og ca. 500 km til Bjørnøya.

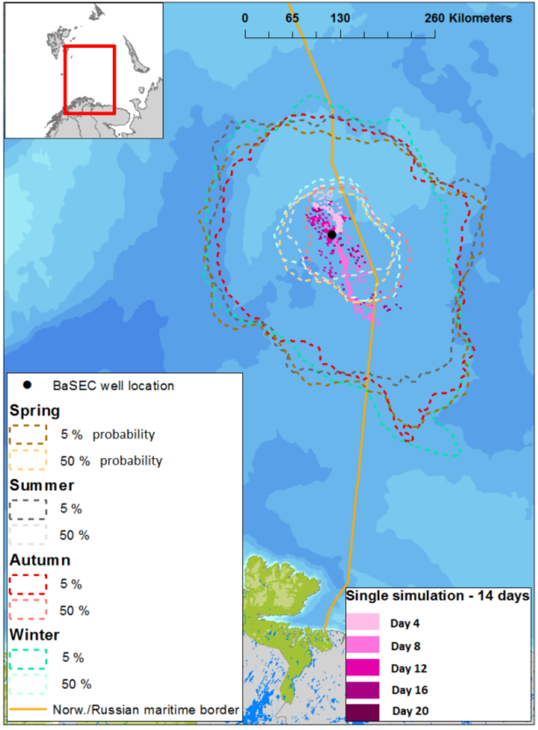
En utblåsning med de utblåsningsratene som er lagt til grunn i dette studiet vil ikke nå land. En utblåsning fra sjøbunn vil ha omtrent samme spredningsområde som et overflateutslipp og man kan forvente at utslippet sprer seg ca. 100 km fra utslippspunktet. Sannsynligheten for at olje på overflaten driver lengre enn dette er begrenset, men oljen kan gå så langt som 200-250 km fra utslippspunktet. Det er relativt liten variasjon i spredning fra sesong til sesong.

Figurene under viser hvilket område man kan forvente olje på overflaten (dvs. mer enn 50 % sannsynlighet som igjen betyr at over halvparten av simuleringene har nådd dette området). Figuren viser også områder som kan ha en viss sannsynlighet for å bli berørt (mellom 5 og 50 % sannsynlighet for å få olje til dette området gitt en

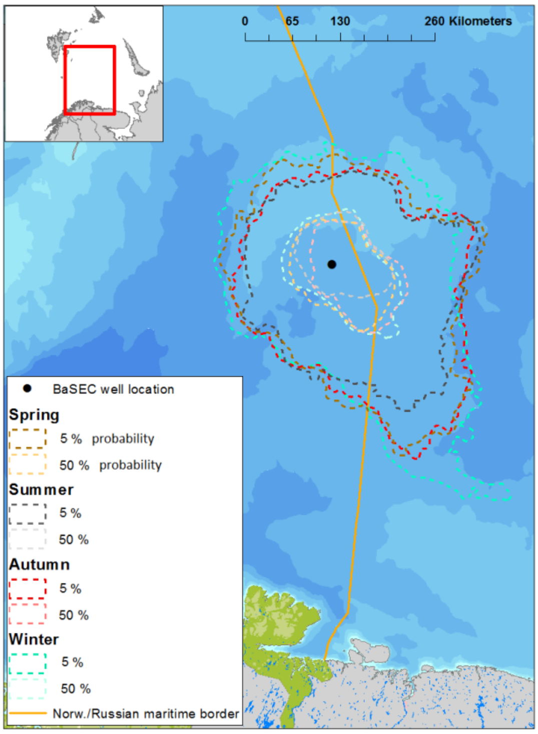
Metode: Det er utført et statistisk representativt antall oljedriftsberegninger for utslippsrater fra 400 opp til 5000 m^3/døgn og utblåsningsvarigheter fra 2 døgn helt opp til 84 døgn. Oljedriftsmodellen OSCAR er benyttet med 4x4 km 3D strømdata (døgnmiddel) og 75x75 km vinddata (hver 3. time) fra perioden 1998 - 2005. Modelleringen er foretatt med daglige data på is konsentrasjoner, også på 4x4 km grid oppløsning. Skrugard olje er valgt som representativ oljetype for området.

utblåsning). Figurene er skilt på overflateutblåsning og utblåsning på sjøbunn i ulike sesonger (vår, sommer, høst og vinter). For figuren med overflateutblåsning til venstre er det også illustrert en tilfeldig valgt enkeltsimulering fra et utslipp som varer i 14 dager. Det er vist hvilket område oljen dekker ved ulike tidspunkt (dag 4, 8, 12, 16 og dag 20).

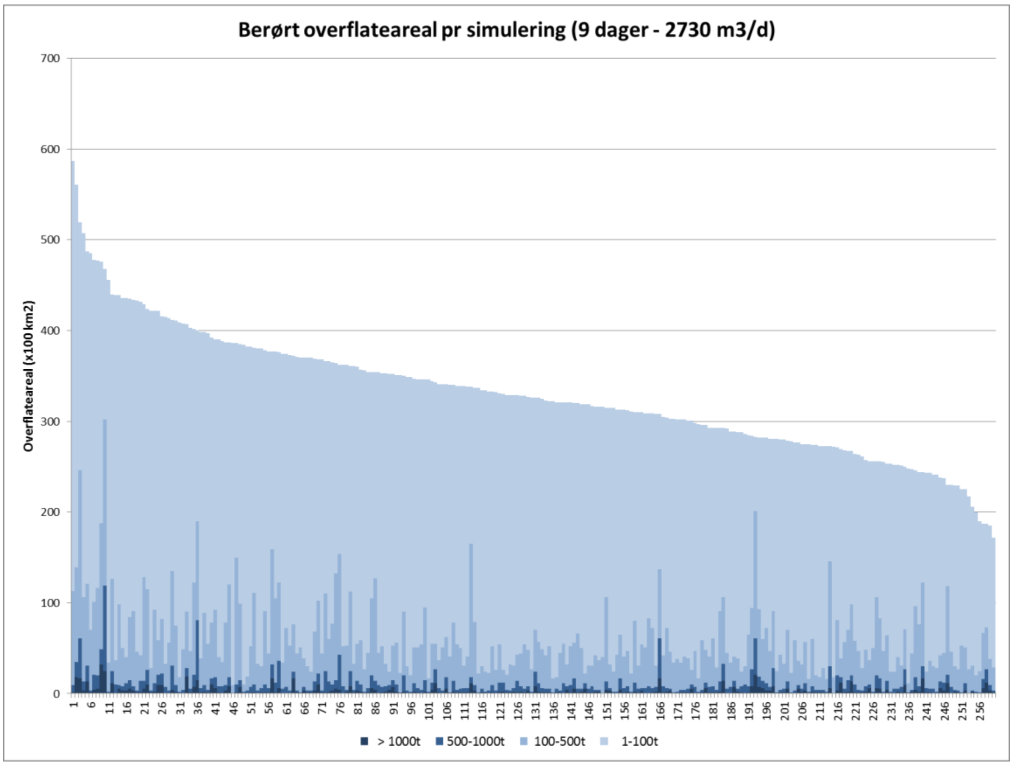
Topside blowout



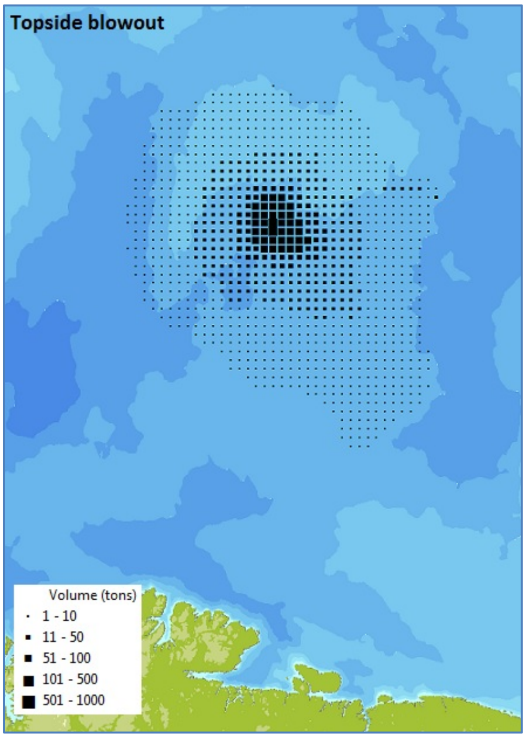
Subsea blowout

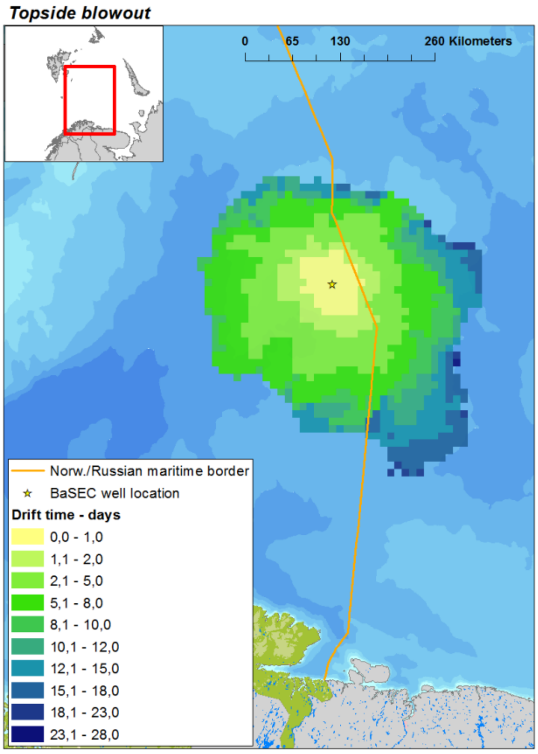


Det er ikke slik at et utblåsning vil dekke hele det statistiske influensområdet slik det er vist i figurene over. Oljens konsentrasjon på overflaten vil også være betydelig redusert jo lengre man kommer vekk fra utblåsningspunktet. Berørt overflateareal i de ulike oljedrift simuleringene er vist i figuren under for et overflateutslipp med vektet utslippsrate og 9 dagers utslippsvarighet, og berører mellom 172 og 587 10x10 km gridruter. I gjennomsnitt berøres 337 ruter eller et areal på 33 700 km^2, noe som tilsvarer ca 17 % av influensområdet.



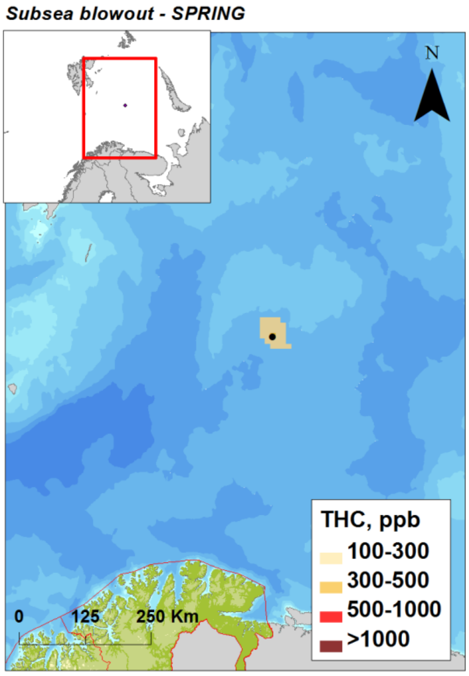
For å gi et statistisk godt bilde også av hvilke oljemengder som er forventet innenfor influensområdet er det i figuren til venstre under presentert forventet oljemengde i tonn innen hver 10x10 km gridrute. Forventet mengde er gitt som en kombinasjon av oljemengde når området blir berørt multiplisert med sannsynligheten for å bli berørt. Figurene viser at det aller meste av oljen fra en utblåsning vil fordeles inntil 100 km fra lokasjonen (figuren gjelder for hele året). Det er også i disse områdene en da vil forvente størst effekt på sjøfugl og sjøpattedyr, selv om denne er begrenset.





Oljens korteste ankomsttid til de ulike områdene er gitt i figuren til høyre over (overflateutblåsning om våren) og viser at drivtid til den norsk-russiske grensen er svært kort (ca 1 døgn). Drivtiden til ytterkanten av influensområdet er på mer enn 8 døgn i vest og over 20 døgn i øst og sør-øst.

I vannsøylen er det genrelt beregnet lave konsentrasjoner og kun et lite område inntil 40 km fra utslippspunktet er forventet å ha oljekonsentrasjoner (THC konsentrasjon) over 100 ppb, som kan gi dødelighet på fiskeegg og -larver. Dette gjelder også kun for de høyeste utblåsningsratene (se figur til høyre) . Det forventes ikke at et så lite effektområde kan gi skader på bestandsnivå for fisk i området som for eksempel på polartorsk.

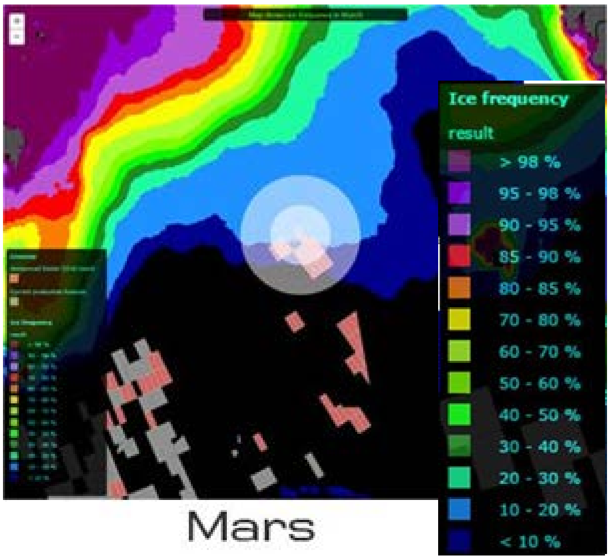


Vil olje fra en utblåsning i dette området nå iskanten?

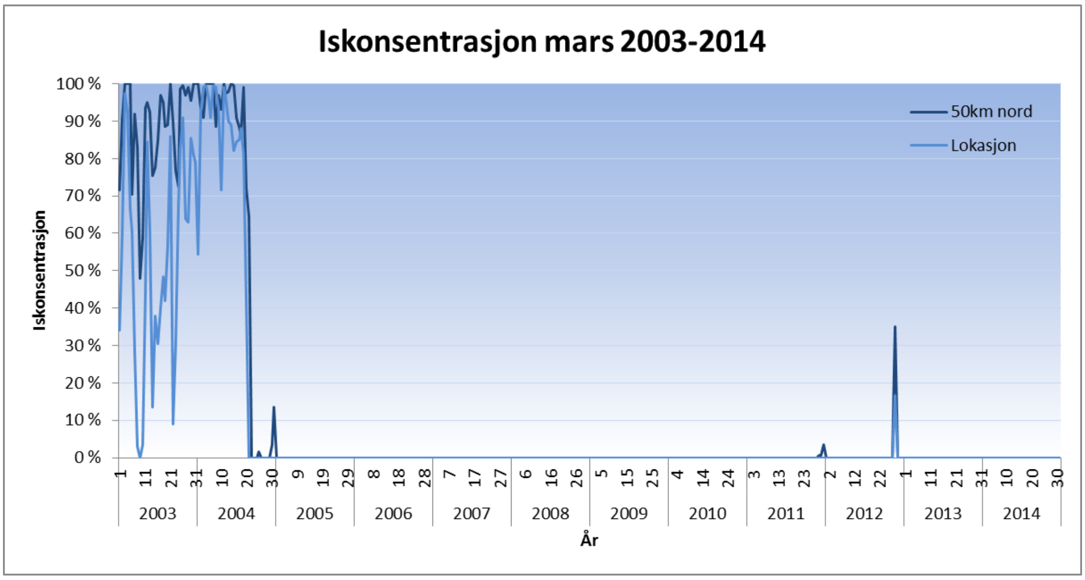
Iskanten er svært variabel fra dag til dag, fra måned til måned og fra år til år. Det benyttes derfor ofte en definisjon på iskanten eller den marginale iskantsonen som det område som har mer enn 30 % sannsynlighet for mer en 15 % is-konsentrasjon. Typisk ser man da på månedlig sannsynlighet basert på mange år med historiske isutbredelser (10-30 år med data).

Metode: I denne studien er det først beregnet hvor ofte ulike is-konsentrasjoner forekommer i området rundt utslippslokasjonen basert på daglige satellittbilder over is-konsentrasjon fra perioden 2003-2014. Basert på oljedriftssimuleringene i perioden 1998-2005 er det videre analysert overlapp mellom oljedrift og is i ulike avstander fra lokasjonen. I tillegg er det gjort noen dag-til-dag detaljstudier av hvordan samvariasjonen mellom oljedrift og iskantforflytning er.

Det er på senvinteren og i vårperioden at iskanten er lengst mot sør. De siste 12 årene har det vært 12 % sannsynlighet for mer enn 15 % iskonsentrasjon på borelokasjonen i perioden januar-april. Det betyr at lokasjonen ligger utenfor det området hvor man definerer iskanten å være (områder med mer enn 30 % sannsynlighet for is). Figuren til høyre viser frekvens for mer en 15 % iskonsentrasjon i mars måned i perioden 2003-2014. Blokk 7435/9 og sirkler med hhv 50 og 100 km radius fra lokasjonen er vist i figuren.



Figuren under viser observert is-konsentrasjon på utslippslokasjonen og 50 km nord av lokasjonen, og den viser at siste gang det var sjøis der var i 2003 og 2004, samt noen dager i mars 2012.



Skulle man få en utblåsning i de tilfeller hvor iskanten går helt inn til lokasjonen vil selvsagt mye av oljen kunne gå inn i isen. Det vil imidlertid ikke være aktivitet i oljeførende lag så lenge isen er nærmere enn 50 kilometer i henhold til norske myndigheters krav. Detaljerte studier av enkeltsimuleringer av olje sammen med utbredelse av is i denne studien har vist at det er svært få eksempler på oljeutslipp som driver inn til iskanten dersom denne er mer enn 50km unna lokasjonen. Selv om man forventer at olje kan drive 100 km så driver den som regel i samme retning som isen, dvs. når isen rykker sørover driver også oljen sørover og når isen trekker seg tilbake kan oljen drive nordover igjen. Studien viser at kun i 2 tilfeller (av 23) i perioden 1998-2005 drev olje inn i isfylte farvann 50 km nord for utslippspunktet. Det ene av disse gangene var i 2004 da isen i perioder var helt nede ved utslippspunktet.

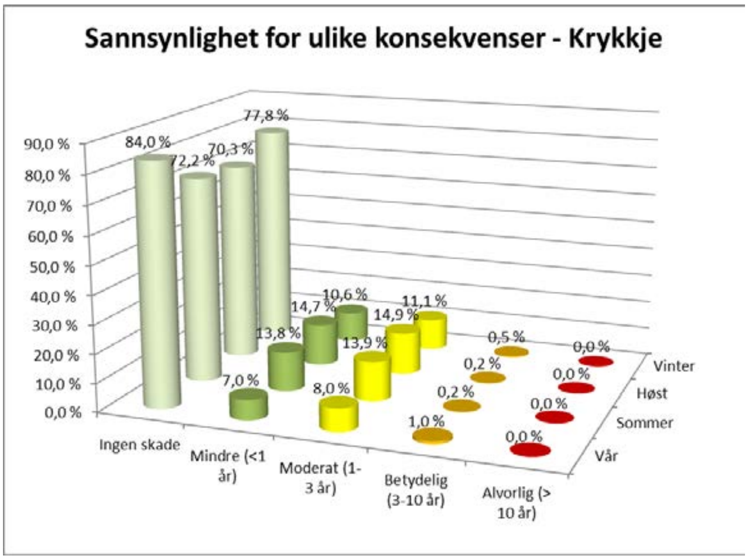
Selv i perioden hvor iskanten har størst utbredelse om våren, så viser studien at det er liten sannsynlighet for at olje vil drive inn til iskanten dersom iskanten er mer enn 50 km unna lokasjonen.

Hvilke miljøkonsekvenser kan en utblåsning i dette området gi?

Miljøkonsekvensene fra en utblåsning er hovedsakelig knyttet til sjøfugl på åpent hav i området rundt lokasjonen.

Metode: I denne studien er analysert på ulike datasett som beskriver fordeling av sjøfugl i åpent hav. Hovedkilden til data er fra SEAPOP programmet (helhetlig og langsiktig overvåkings- og kartleggingsprogram for norske sjøfugler). Der foreligger data på månedlig fordeling av sjøfugl i åpent hav for en rekke arter. Det er videre analysert på kolonispesifikke datasett for lomvi, som er basert på observasjonsdata fra lys-loggere (SeaTrack data). I tillegg er det spesifikt for dette studiet utviklet et tilpasset datasett for ismåke, en art som arter oppholder seg i iskantsonen. Datasettet beskriver utbredelse av ismåke i 20-50 % is-konsentrasjon for de samme perioder hvor det er kjørt oljedriftmodelleringer (i vårperioden 1998-2005). Datasettet kan også være relevant for andre arter i iskantsonen også (f.eks. sel).

Ved en utblåsning fra blokk 7435/9 vil krykkje være den av sjøfuglene som vil bli mest berørt. Mest sannsynlig vil det likevel ikke bli skade på bestandsnivå for krykkje for noen av sesongene basert på utbredelsen av krykkje i SEAPOP dataene (se figur til høyre). Det er inntil 30 % sannsynlighet for mindre eller moderat miljøskade (inntil 3 års restitusjonstid for bestanden) med størst sannsynlighet for skade i sommer eller høstperioden. Det er under 1 % sannsynlighet for betydelig miljøskade (3-10 års restitusjonstid for bestanden).



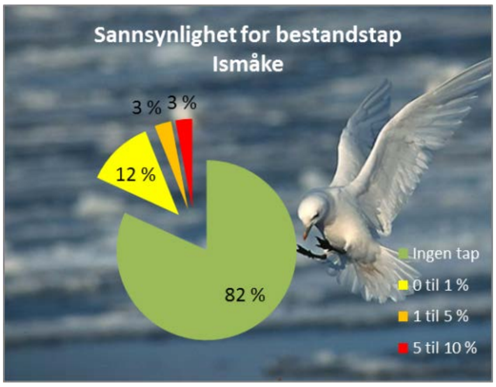
Lomvi vil ha lavere sannsynlighet for bestandstap enn krykkje, og de kolonispesifikke datasettene for lomvi viser at kolonien ved Sklinna har størst sannsynlighet for å bli berørt i høstperioden hvor lomvi fra alle kolonier samles i den sørøstlige delen av Barentshavet før de på senvinteren trekker tilbake mot sine hekkekolonier.

Ressurser i iskantsonen

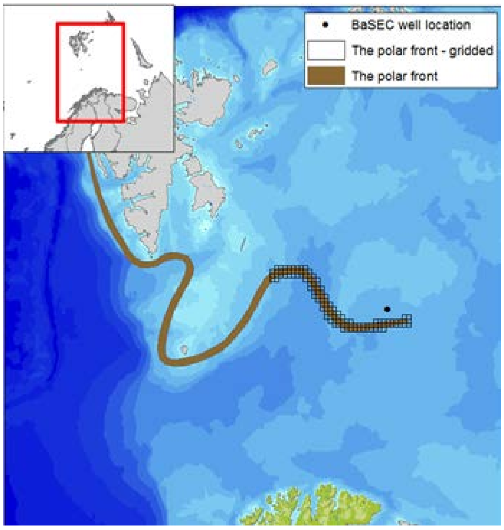
Det foreligger lite spesifikke data for utbredelse av sjøfugl og sjøpattedyr langs iskanten. For å regne miljørisiko er det derfor utarbeidet et datasett på ismåke, en art som oppholder seg langs iskanten hele året i områder med 20-50 % iskonsentrasjon.

Resultatene av denne konsekvensberegningen viser liten sannsynlighet for at olje når områder med 20-50 % iskonsentrasjon, og dermed begrensede påvirkning på arter som oppholder seg der slik som ismåka. Grafen under viser at det er beregnet 82 % sannsynlighet for ingen påvirkning på ismåke og

12 % sannsynlighet for inntil 1 % bestandstap i vårperioden (februar-april). Slike datasett tilpasset i tid og rom øker presisjonen og reduserer usikkerheten i konsekvensberegningene/-vurderingene, spesielt for arter der tilstedeværelsen i stor grad er bestemt av ytre faktorer som endrer seg mye på kort tid og fra år til år, som økosystemene tilknyttet iskanten. En forventer derfor ikke større påvirkning på andre arter i iskantsonen slik som sel eller isbjørn. Ettersom konsentrasjoner i vannsøylen generelt er under effektgrensen for effekter på fiskeegg og -larver, forventes heller ikke påvirkning på fiskebestander i iskantområdet.



Polarfronten



Det foreligger ikke gode konkrete datasett for biologiske ressurser i området ved polarfronten (skille mellom varmt atlantisk vann og kaldt arktisk vann). SEAPOP dataene på utbredelse av sjøfugl i åpent vann gir ingen klare indikasjoner på større tetthet av fugl i dette området. Om man likevel antar at alle fugler i en sårbar fuglebestand befinner seg innenfor SVO (*Særlig Verdifullt Område*) polarfront i området sørøst av Hopen og østover, vil man kunne forvente et bestandstap på 8,2 % på en slik bestand ved en overflateutblåsning i vårperioden.

Miljørisikonivå

Sannsynligheten for en oljeutblåsning fra en letebrønn i området er basert på historiske data fra SINTEF offshore blowout database og er beregnet til 1.41×10^{-4} per leteboring, som tilsvarer en utblåsning for hver 7092 letebrønn eller en risiko for utblåsning på 0,014 %. Selskapenes miljøakseptkriterier for ulik miljøskade ved leteboringsaktivitet er:

- 1 mindre miljøskade for hver 1000 leteboring
- 1 moderat miljøskade for hver 4000 leteboring
- 1 betydelig miljøskade for hver 10 000 leteboring
- 1 alvorlig miljøskade for hver 40 000 leteboring

Beregnet miljørisiko for de ulike skadekategoriene er gitt i tabellen under og er på maksimalt 8,2 % av selskapenes akseptgrense (gitt som 100 %), altså godt innenfor de angitte akseptkriteriene. Tabellen under viser miljørisiko (andel av akseptkriteriene) for alle tre datasett som det er beregnet på.

Sesong	VØK	Mindre miljøskade (< 1 år)	Moderat miljøskade (1 - 3 år)	Betydelig miljøskade (3 - 10 år)	Alvorlig miljøskade (> 10 år)
Vår	Krykkje (SEAPOP data)	1,2 %	5,0 %	0,3 %	0,0 %
	Lomvi (lyslogger data)	-	-	-	-
	Ismåke (iskant datasett)	0,3 %	1,7 %	1,1 %	0,0 %
Sommer	Krykkje (SEAPOP data)	1,8 %	7,1 %	0,1 %	0,0 %
	Lomvi (lyslogger data)	-	-	-	-
	Ismåke (iskant datasett)	-	-	-	-
Høst	Krykkje (SEAPOP data)	2,1 %	8,2 %	0,2 %	0,0 %
	Lomvi (lyslogger data)	1,4 %	6,1 %	0,8 %	0,2 %
	Ismåke (iskant datasett)	-	-	-	-
Vinter	Krykkje (SEAPOP data)	1,4 %	5,9 %	0,3 %	0,0 %
	Lomvi (lyslogger data)	0,3 %	1,1 %	0,0 %	0,0 %
	Ismåke (iskant datasett)	-	-	-	-

Hvilke oljeverntekniker vil kunne fungere best ved en utblåsning i blokk 7435/9?

En oljevernberedskapsanalyse er utført for et utblåsningsscenario fra blokk 7435/9. Studiet tar for seg ulike beredskapsteknikker både i åpent hav og i isfylte farvann og belyser hvilke teknikker som kan fungere best på en eventuell utblåsning i dette området.

Metode: I denne studien er ulike beredskapsteknikker analysert på, inkludert:

- Mekanisk opptak med både passive og aktive lensesystemer
- Kjemisk dispergering både fra fly og fra fartøy
- Brenning (in-situ-burning) – fremtidig konsept
- Undervannsdispergering (subsea dispersion) – fremtidig konsept
- I tillegg er det sett på et multipurpose fartøyskonsept for operasjoner også i isfylte farvann opp til 30 % is-konsentrasjon – fremtidig konsept

Det er også sett på ulike kombinasjoner av disse teknikkene. Teknikker i åpent hav er modellert i SINTEF's oljedriftmodell OSCAR, mens effekt av oljevern i områder med is er beregnet ved hjelp av et DNV GL utviklet verktøy ORCA (Oil Spill Response Calculator). Studien har sett på både en overflateutblåsning på 2735 m^3/døgn i 9 dager, samt en sjøbunnsutblåsning på 1730 m^3/døgn i 16 dager. Som i miljørisikoanalysen er en Skrugard råolje lagt til grunn for beregningene.





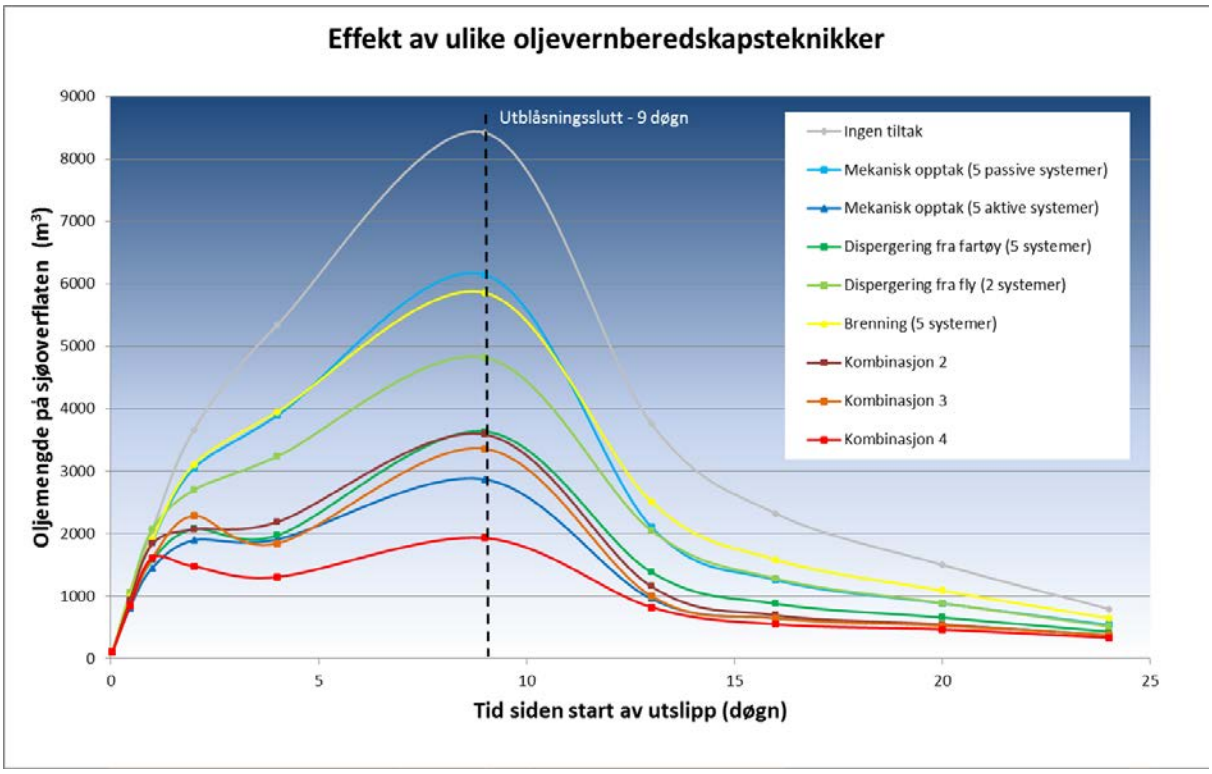


Resultatene viser at beredskapsteknikkene er mer effektive om sommeren enn om vinteren og mer effektive på en overflateutblåsning enn på en sjøbunnsutblåsning i dette området. Tradisjonelt mekanisk opptak med passive lensesystem kan ta opp maksimalt 24 % om sommeren vs. 12 % om vinteren. Kjemisk dispergering fra fartøy øker oljemengden i vannsøylen fra 60 % til 75 % om sommeren og fra 65 % til 76 % om vinteren.

Mekanisk opptak med aktive lensesystemer (CB6/CB8 eller MOS Sweeper) viser seg å kunne ta opp dobbelt så mye olje som passive lensesystemer (maksimalt 55 % vs. 24 % om sommeren), i hovedsak på grunn av høyere operasjonshastighet med slike lensesystemer. Det er noe høyere effekt av kjemisk dispergering med 5 fartøy vs. 2 fly, trolig fordi de fem fartøyene kan operere på flere ulike oljeflak samtidig.

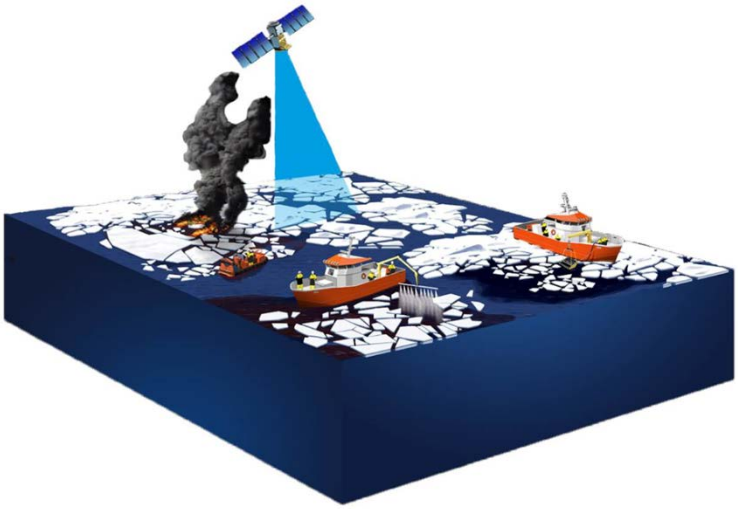
Størst effekt gir en kombinasjon av mekanisk opptak med aktive systemer og dispergering fra fly (kombinasjon 4 i grafen under). Iht. modelleringen kan en slik kombinasjon redusere mengden olje på overflaten med inntil 75 % de første 5 dagene etter en overflateutblåsning pga. kombinasjon av økt nedblanding og opptak (gjennomsnittstall for hele året).

Subsea dispergering viser seg å ha begrenset effekt på en sjøbunnsutblåsning, men her er det usikkerhet rundt modellberegningene og dette vil kunne variere med utslippsspesifikke forhold. Grunnet rask og høyt vannopptak hos Skrugard olje vil in-situbrenning ha begrenset effekt. Dette vil også gjelde dersom olje kommer inn i isfylte farvann. Av de vurderte teknikkene er det mekanisk opptak som viser størst potensiale i is-konsentrasjoner opp til 30 %.



Hva er utfordringene ved å drive oljevern i kaldt klima og i isfylte farvann?

Det er flere aktuelle oljeverntiltak for å bekjempe oljeutslipp i arktiske marine miljøer. De viktigste alternativer er fjernmåling, mekanisk oppsamling, kjemisk dispergering og in-situbrenning. Hver av disse kategoriene har flere varianter, og avhengig av bl.a. utslippsrelaterte forhold kan ulike tiltak bestå av og settes sammen med ulike egenskaper og tilpasset ulike forhold. De mest aktuelle tiltakene er vurdert i forhold til innvirkning av kulde og is. Andre momenter slik som logistikk, øving/trening, planlegging og HMS er også skissert.



Flere øvelser har blitt utført i Finnmark vinteren 2015. En øvelse ble også gjennomført i iskanten senvinteren 2015. Øvelsene har gitt verdifull informasjon og erfaringer om norsk oljevernberedskap i kaldt klima og is, og underbygger de utførte beregninger. Øvelsen demonstrerte bl.a. at et vanlig NOFO-system kan settes ut og opereres etter dagens prosedyrer. Anti-is middel (glykol) kan benyttes på sentrale komponenter for å motvirke ising. NOFO systemet fungerer effektivt så lenge man unngår store is konsentrasjoner. Ved tilstedeværelse av is må det forventes en redusert effektivitet pga. regelmessig avbrudd i operasjonen for å fjerne is-ansamlinger. Den reduserte effektiviteten på grunn av slike avbrudd vil styres av is-mengder og temperatur.

Øvelsene i Finnmark viser at også streng kulde og vind vil kunne redusere effektiviteten i oljevernoperasjoner bl.a. pga. ising på utstyr og fare for frostskader på personell som krever særlige hensyn. Evalueringen av deteksjonsteknikker for olje i isfylte farvann tilsier at en robust og fleksibel strategi for arktiske forhold krever en kombinasjon av luftbårne, satellitt- og overflatebaserte teknologier med fler-

Metode: En kvantitativ metode for vurdering av oljevernberedskapens sesongmessige og geografiske anvendbarhet er anvendt. Metodikken er basert på en analyse som kombinerer definerte begrensninger for oljevernberedskap med omfattende metocean data. Metodikken muliggjør beregning av relative, gjennomsnittlige effektiviteter for de mest aktuelle responstiltakene i Barentshavet i forhold til begrensende miljøparametere slik som vind, bølger, is, temperatur, sikt og mørke. Beregninger etter denne metoden viser at det gjennomsnittlig er fullt mulig å utføre oljevernoperasjoner i isfrie farvann året rundt, men at forholdene generelt varierer fra gunstige i sommerhalvåret til krevende i vinterhalvåret. I områder med sjøiskonsentrasjoner over 30 % kreves det teknikker og utstyr som særskilt tilpasset isforholdene. Oljedrift og is i ulike avstander fra lokasjonen. I tillegg er det gjort noen dag-til-dag detaljstudier av hvordan samvariasjonen mellom oljedrift og iskantforflytning er.

sensor kapasitet. Hovedutfordringen er deteksjon av olje under snø og is, eller olje innkapslet i is. For isfrie farvann er eksisterende og tilgjengelige løsninger på norsk sokkel dekkende, men datakommunikasjon kan langt nord være en begrensende faktor. Tiltak for å forbedre digital kommunikasjon fra skip viser gode resultater, og digitale downlink-systemer fra fly fungerer også godt. Slike systemer vil kunne fungere både som overføringsmedium for informasjon mellom enheter lokalt, samt overføring av informasjon mellom fly og skip, og fra skip til land via fly.

Dersom et oljeutslipp skulle drive inn i Russisk farvann er det etablert en overenskomst mellom Norge og Russland angående samarbeid om bekjempelse av oljeforurensning i Barentshavet. I medhold av avtalen er det utarbeidet en felles Norsk-Russisk beredskapsplan for oljevernaksjoner i Barentshavet. Planen regulerer samarbeid mellom myndigheter i de to landene når det gjelder aksjoner mot oljeutslipp, gjennomføring av øvelser og jevnlige møter.

Anbefalinger

Det foreslås at fartøy som skal brukes året rundt i den nordlige delen av området inkludert i 23. runde bør tilfredsstille krav til isklasse og vinterisering. Ytterligere anbefalinger er å etablere en vinteriseringsstandard for oljevernutstyr, og driftsprosedyrer for dette i kaldt klima og is. En mal for reservedeler og utstyr for NOFO operasjoner i nordlige farvann bør også være forberedt, samt at det bør utvikles et treningsprogram for oljevernaksjoner i kaldt klima og is. Studien indikerer at aktive mekaniske opptaks-systemer for offshore forhold bør vurderes som et tillegg til eksisterende opptaks-systemer. Konseptet er godt utprøvd i kystnære farvann, og realistiske offshore tester har vist lovende resultater. Aktive lensesystemer kan gi høyere oppsamlingsrate enn passive lensesystemer, noe som er en suksessfaktor ved mekanisk bekjempelse. Andre fordeler er økt manøvrerbarhet og at systemet kan opereres med ett fartøy. Andre områder som bør følges opp er planlegging og testing av logistikk-kjeder i avsidesliggende områder.

Operatørens vurdering av miljørisiko

[Tekst fra operatøren]

Environmental risk assessment for oil blowout from exploration drilling in the Barents Sea South-East

Statoil ASA

Report No.: 2015-0985, Rev. 1
Document No.: 1T1SS0A-9
Date: 2015-12-13

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1	2015-12-13	Corrected minor errors in spelling			

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EXECUTIVE SUMMARY

On behalf of BaSEC, the Barents Sea Exploration Collaboration; a joint effort including Statoil ASA, Eni Norge, Lundin Norway, OMV and ENGIE, DNV GL has carried out a damage-based environmental risk analysis and an oil spill contingency analysis for a potential drilling operation in block 7435/9, and prepared a status document on oil spill response in ice infested and cold waters. The results from each study are presented in separate reports. The following report presents the environmental risk analysis part of the studies.

Block 7435/9 is situated in the most remote area within the opened acreage of the Barents Sea, approximately 380 km from the nearest land area; the island Hopen, which is part of the Svalbard archipelago, located north-west of the block. The distance to the Norwegian mainland is approximately 440 km, whereas the distances to the Russian coastal areas are longer. The distance to the Norwegian-Russian maritime border is approximately 30 km.

The environmental risk analysis includes oil spill modelling of the dimensioning spill scenario; a topside or subsea oil blowout from the well during drilling with rates ranging from 400 Sm^3/day to 5000 Sm^3/day and durations from 2-84 days, based on oil properties for the Skrugard crude oil (871 kg/Sm^3). The result of the modelling showed that the potential effects will most likely be limited to the open sea areas and resources present at the sea surface. The probabilities for oil drifting to shore are extremely small (<0.5 %, with the highest probability of oil stranding at the south-eastern part of Svalbard). The shortest drift time to shore is approximately 40 days. Sea surface oil is expected to cross the Norwegian-Russian maritime border within 1 day after the start of the release.

The analysis of potential oil pollution in the marginal ice zone (≥15 % concentration) was seen to be relevant only in the late winter/early spring when the polar sea ice is at its maximum. This analysis indicates that the prevailing weather conditions affecting the position of the marginal ice zone also affects the drift and distribution of surface oil, but one can expect that ice concentrations exceeding a certain level will behave differently, and to a lesser degree be determined by the forces acting on sea surface oil. At rather rare weather conditions the sea ice may move as far south as to cover the actual release location, causing the oil to be trapped within/underneath the ice. In such cases one can expect natural resources associated with the marginal ice zone, such as Ivory gull and a number of different marine mammal species, to be particularly vulnerable. Oil hit probability in partially ice infested areas indicates very limited overlap (2 out of 117 simulations) between oil and ice (concentration ≥ 15 %) 50 km to100 km areas north of the release location. At 150 km north of the release location no overlap is observed. The drift time to these areas varies between 14 and 24 days.

The datasets on environmental resources included in the quantitative analysis are seabirds at the open sea and in coastal areas (Seapop, 2013 and 2012), marine mammals in coastal areas (DN & HI, 2007), DNV GL developed dynamic datasets for a species in the marginal ice zone (Ivory gull), gls-logger data for Common Guillemot, and DNV GL prepared dataset for species with a strong connections to the Polar front area. The environmental risk analysis has demonstrated that pelagic seabirds are the dimensioning resource with regards to risk within the study area. A conservative dataset prepared specifically for the Polar front area indicates that resources with a strong connection to the Polar front do have a potential for higher population losses given oil exposure, compared to widely distributed seabirds as modelled by Seapop. A more realistic dynamic datasets has been prepared for Ivory Gull in the marginal ice zone (20-50 % ice concentration) and matched in time with the oil spill simulations. This dynamic modelling of consequences and risk has proved limited potential for oil reaching the Ivory Gull habitat; hence limited consequence and risk for this species. Dynamic resource modelling is a measure to increase the precision and reduce the uncertainties of consequence assessments in a very dynamic system like the ice edge ecosystem.

An analysis of total hydrocarbon concentrations in the water column has proved no measurable impact for eggs/larvae based on the lower limit for effects of 100 ppb THC.

Compared to commonly used acceptance criteria in environmental risk analyses at the Norwegian Continental Shelf, all calculated risks related to a blowout from Block 7435/9 are well within acceptable levels, even basing the analysis on conservative assumptions such as limiting the resources to i.e. a relatively small static Polar front area.

The dynamic seabird data for the marginal ice zone gives low risk (< 2 % of the acceptance criteria for *Moderate* environmental damage (1-3 years restitution time)), as the potential for oil entering this zone is very limited. The data is also only relevant in a limited time of the year, when the sea ice is at its maximum southern orientation.

The gls-data shows that Common guillemot from several colonies uses the in the Barents Sea as wintering area, however mainly the south-western parts, and the potential for conflicts with the area at question in this analysis is limited (risk calculated to 6 % of the acceptance criteria for *Moderate* environmental damage).

Out of the Seapop-datasets only seabirds at the open sea are at risk of oil exposure above the lower threshold of effects (one tonne per 10 × 10 km^2 area). The Black-legged kittiwake is the species most at risk, with up to 8 % of the acceptance criteria for *Moderate* environmental damage.

The environmental risk analysis for (species connected to) the Polar front area is based on the defined *area of particular environmental vulnerability*. The calculated environmental risk for the population restricted to the Polar front is 30 % of the acceptance criteria for *Serious* environmental damage (> 10 years restitution time).

SAMMENDRAG

På vegne av BaSEC, Barents Sea Exploration Collaboration, et samarbeid mellom Statoil ASA, Eni Norge, Lundin Norway, OMV og ENGIE, har DNV GL gjennomført en skadebasert miljørisikoanalyse og en miljørettet beredskapsanalyse for en potensiell boreoperasjon i blokk 7435/9, samt utarbeidet et statusdokument for oljevernberedskap i tidvis islagte farvann. Resultatene fra hvert studium er presentert i separate rapporter. Foreliggende rapport beskriver miljørisikoanalysen/-vurderingene av studiene.

Blokk 7435/9 er lokalisert i den mest avsidesliggende delen av den nylig åpnede delen av Barentshavet, om lag 380 om fra nærmeste land som er Hopen; en øy som inngår i øyområdet Svalbard, nordvest for blokken. Avstanden til fastlandet i Norge er om lag 440 km, mens avstanden til Russiske kystområder er lengre. Avstanden til den maritime grensen mellom Norge og Russland er om lag 30 km.

Miljørisikoanalysen inkluderer oljedriftsmodellering av dimensjonerende scenario; en overflateutblåsning eller sjøbunnsutblåsning fra brønnen under boring, med utblåsningsrater i størrelsesorden fra 400 til 5000 Sm^3/døgn og varigheter fra 2 til 84 døgn. Skrugard råolje (tetthet 871 kg/Sm3) er lagt til grunn som referanseolje. Resultatene av modelleringen viser at potensielle effekter av en oljeutblåsning i dette området mest sannsynlig vil være begrenset til havoverflaten og naturressurser i åpent hav. Sannsynligheten for at olje skal drive til kystområdene er veldig liten (< 0,5 %, med høyeste sannsynlighet for stranding av olje i sør-østlige deler av Svalbard). Korteste drivtid til land er om lag 40 døgn. Olje på havoverflaten forventes å krysse den maritime grensen til Russisk farvann innen 1 døgn etter utslippsstart.

Analysen av mulige oljepåslag i den marginale issone (≥15 % konsentrasjon) viste at dette kun er relevant i perioden sen vinter/tidlig vår når havisen har maksimum sørlig utbredelse. Analysen indikerer at rådende værforhold vil påvirke både orienteringen av den marginale issone og oljedriften på havoverflaten, noe som minske sannsynligheten for oljepåslag. Ved høyere iskonsentrasjoner kan en imidlertid forvente en annen oppførsel på havoverflaten og at isdriften i mindre grad vil være bestemt av værforholdene som påvirker oljedriften. Ved mer sjeldne værforhold kan isdekket strekke seg så langt sør at det dekker utslippslokasjonen, og medføre at olje blir innkapslet i/under isen. I slike tilfeller kan en forvente at naturressurser som oppholder seg i tilknytning til isen, eksempelvis ismåke og ulike marine pattedyr, vil være ekstra utsatt. Treffsannsynligheten i tidvis islagte farvann indikerer liten grad av overlapp (2 av 117 simuleringer) mellom olje og is (med konsentrasjoner ≥ 15 %) i 50 km og 100 km avstand fra utslippspunktet. 150 km nord for utslippspunktet er det ikke registrert noe overlapp mellom olje og is. Drivtiden til disse områdene varierer fra 14 til 24 døgn.

Datasettene for naturressurser inkludert i den kvantitative analysen er sjøfugl i åpent hav og kystområdene (Seapop, 2013 og 2012), marine pattedyr i kystområdene (DN & HI, 2007), et dynamisk datasett for arter i den marginale issone (ismåke) utviklet av DNV GL, lys-logger data for lomvi, og et datasett som beskriver sjøfuglarter på havoverflaten med sterk tilknytning til polarfronten (utarbeidet at DNV GL). Resultatene av miljørisikoanalysen viser at sjøfugl i åpent hav er dimensjonerende for risikonivået. Datasettet som beskriver arter tilknyttet polarfronten gir høyest beregnet risiko (om lag 30 % av de «normale» akseptkriteriene for denne typen aktivitet), men det må understrekes at dette er basert på svært konservative antagelser. Et dynamisk datasett, som det utviklet for ismåke i den marginale issonen, gir et betydelig mer realistisk bilde på forventede konsekvenser av et oljeutslipp i dette området. I dette datasettet er faktisk isutbredelse (og antatt utbredelse av sjøfugl) koblet sammen i tid og sted. Resultatene av denne modelleringen viser begrenset potensiale for at olje når ishabitatene, og dermed begrensede konsekvenser og risiko for arter som oppholder seg der. Dynamisk modellering øker presisjonen og reduserer usikkerheten i konsekvensberegningene/-vurderingene, spesielt for arter der

tilstedeværelsen i stor grad er bestemt av ytre faktorer som endrer seg mye på kort tid og fra år til år, som økosystemene tilknyttet iskanten.

Analysen av hydrokarbonkonsentrasjoner i vannsøylen viste ingen målbare effekter på egg eller larver, basert på nedre grenseverdi av 100 ppb THC.

Beregnet risikonivå er målt opp mot de mest vanlige akseptkriteriene brukt i miljørisikoanalyser for letebrønner på den norske kontinentalsokkel. Basert på denne sammenligningen er risikonivået på et akseptabelt nivå, også forutsatt konservative antagelser som gjort for arter tilknyttet polarfronten.

Den dynamiske modelleringen for sjøfugl i den marginale issone gir lav risiko (< 2 % av akseptkriteriet for *Moderat* miljøskade; 1-3 års restitusjonstid), noe som gjenspeiler den lave sannsynligheten for oljepåslag i issonen. I tillegg er det viktig å merke seg at dataene kun er relevante i en begrenset tid av året; nå isen har maksimal sørlig utbredelse.

Lysloggedataene viser at lomvi fra flere ulike kolonier bruker Barentshavet også som overvintringssted, men hovedsakelig de sør-vestlige deler, og potensielle konflikter med aktiviteten vurdert i denne analysen er begrenset (høyeste risiko beregnet til 6 % av akseptkriteriet for *Moderat* miljøskade).

Analysen av risiko for sjøfugl basert på Seapop-datasettene viser at kun sjøfugl i åpent hav eksponeres for olje over nedre grenseverdi (1 tonn olje per 10 × 10 km^2). Basert på Seapop-datasettene er det høyest risiko for skade på krykkjebestanden i Barentshavet, med inntil 8 % av akseptkriteriet for *Moderat* miljøskade.

Miljørisikoanalysen for arter tilknyttet polarfronten er basert på det definerte *Særlig Verdifulle Området* (SVO). Beregnet miljørisiko basert på dette datasettet gir høyest risiko, med 30 % av akseptkriteriet for *Alvorlig* miljøskade (> 10 års restitusjonstid).

DEFINITIONS AND ABBREVIATIONS

Acceptance criteria	The criteria defines the maximum allowed occurrence of accidents that can cause an environmental damage with a given recovery time. The classification is in line with the OLF guidance for environmental risk analysis (OLF, 2007).
ALARP	As Low As Reasonably Practicable. ALARP expresses that the risk level is reduced (through a documented and systematic process) so far that no further cost effective measure is identified.
Analysis area	Area that make the basis for environmental risk analyses and that are larger than the influence area (influence area is a result of oil drift modelling). The resource description is carried out in the analyses area to make sure the size of the area is sufficient.
APES	Areas of particular environmental sensitivity.
DSHA	Defined Situations of Hazard and Accident. DSHA is a selection of hazardous and accidental events that will be used for the dimensioning of the emergency preparedness for the activity and Environmental Risk Analysis.
ERA	Environmental Risk Analysis.
GLS	Geolocator (used for seabird logging).
GOR	Gas Oil Ratio.
Hit probability	The probability that a given 10 × 10 km grid is hit by oil from a potential oil spill.
Influence area	A defined area with 5 % or more probability for pollution within a 10 × 10 km grid if an oil discharge has taken place.
MIZ	Marginal ice zone, defined as the area with ≥ 15 % ice concentration (cover) in more than 30 % of the time (Klima - og Miljødepartementet, 2015) .
MIRA	Method for environmental risk analysis (OLF, 2007).
MSL	Mean Sea Level.
NCS	Norwegian Continental Shelf.
OLF	Previous name for The Norwegian Oil and Gas Association.
OSCAR	Oil Spill Contingency And Response model (SINTEF).
PL	Production License.
ppb	Parts per billion.
Restitution/recovery time	Recovery is achieved when the animal- and plant life in the affected environment has returned to the same level as before the oil spill (natural variation considered), and the biological processes works normally.

	Restitution time is the time from an oil spill occurs until the recovery is achieved.
THC	Total Hydrocarbon Concentration.
VEC	Valued Ecosystem Component. Recourses with high vulnerability and conservation value. VECs are chosen as dimensioning resources in the analysis due to high vulnerability to oil pollution and/or high degree of presence in the analytic area. VECs are species that are likely to be affected in the analysis.

1 INTRODUCTION

1.1 Objective

The current environmental risk analysis (ERA) aim to address the environmental consequences and risk associated with an exploration drilling in block 7435/9, the northernmost block announced in the Barents Sea 23rd licencing round area. The project is part of the BaSEC, Barents Sea Exploration Collaboration, a joint effort between Statoil ASA, Eni Norge, Lundin Norway, OMV and ENGIE to solve operational task tied to petroleum exploration in the Barents Sea. More recently several additional companies have joined BaSEC. This analysis is a preparation for a potential drilling campaign to point out potential environmental challenges related to petroleum activity in the area. It is one out of three separate studies carried out by DNV GL; the second being an Oil Spill Contingency Analysis (DNV GL, 2015a) and the third being an oil spill response *Status Document* (DNV GL, 2015b).

The environmental risk assessment is performed as a damage-based analysis, in accordance with the Norwegian oil and gas (formerly OLF) guideline for environmental risk analyses for petroleum activities on the Norwegian Continental Shelf (OLF, 2007b). A brief description of the methodology is provided in Chapter 4 and more extensive information is provided in Appendix A. Relevant oil spill scenarios are identified and modelled, forming the basis for the selection of natural resources to be given special focus (further described in Chapter 5.1).

1.2 Activity description

The defined scenario is an exploration drilling operation in the north-eastern part of the Norwegian economic zone of the Barents Sea (Barents Sea south-east, see Figure 1-1 for location of block 7435/9 and the well), using a semi-submersible rig.

Figure 1-2 shows the distances from the well location to specific land areas (Svalbard, coast of Norway and Russia and Novaya Zemlya). The well location is in a remote area, at a distance of approximately 440 km from mainland Norway; Nordkinnhalvøya in Finnmark. The island Hopen, in the south-eastern part of the Svalbard archipelago, is the closest land area, about 380 km to the northwest of the well location. The distance to Spitsbergen, the largest island at Svalbard, is longer with about 470 km. The distance to the coastal areas of Russia exceeds 500 km, the distance to Novaya Zemlya is about 530 km, and the distance to the Norwegian-Russian maritime border is approximately 30 km. The water depth at the location is 228 meters MSL.

Parameters used as input to the environmental risk analysis are given in Table 1-1.

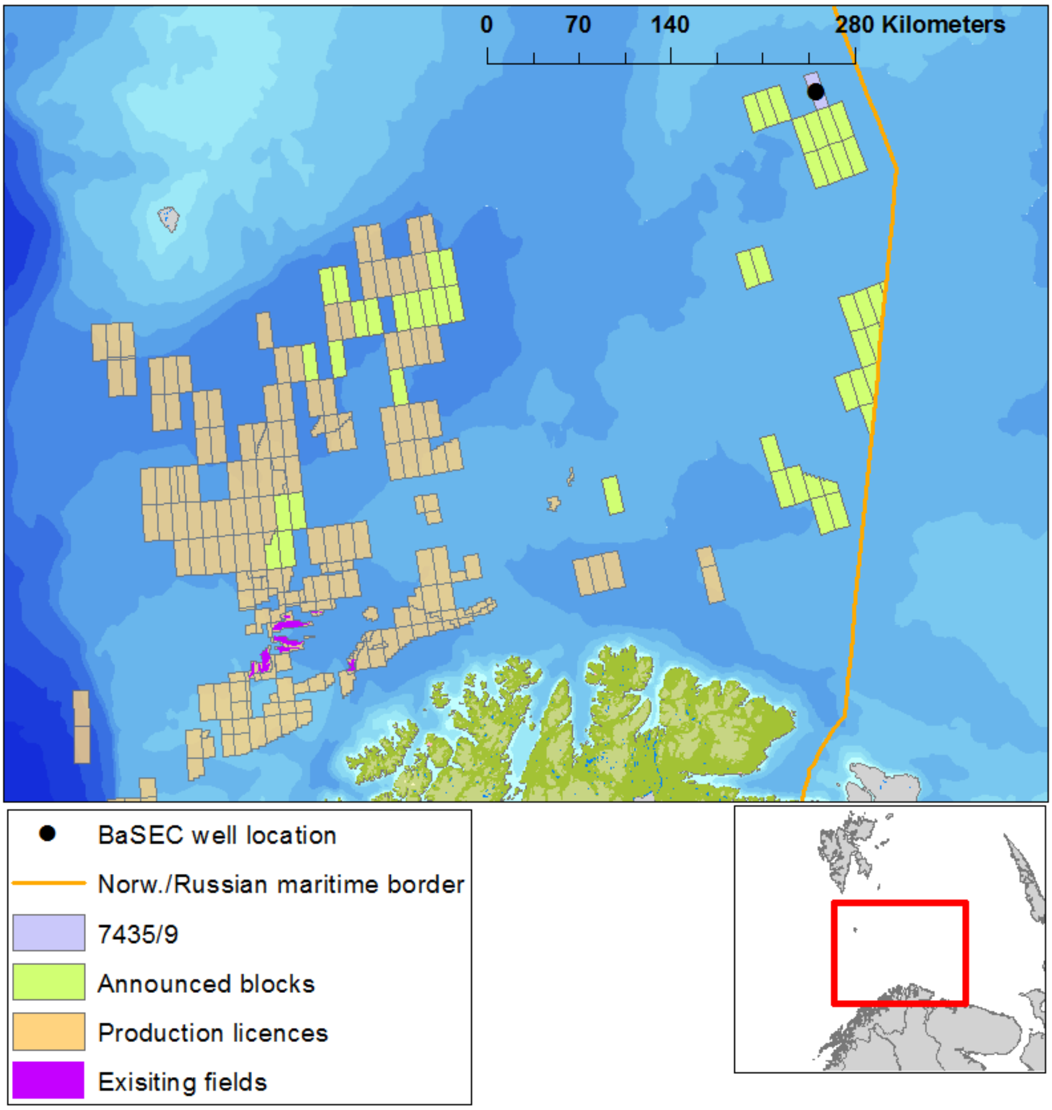

Figure 1-1 *Existing production licences and fields and proposed new areas considered opened for petroleum exploration in the Barents Sea. Well location and block 7435/9 are highlighted.*

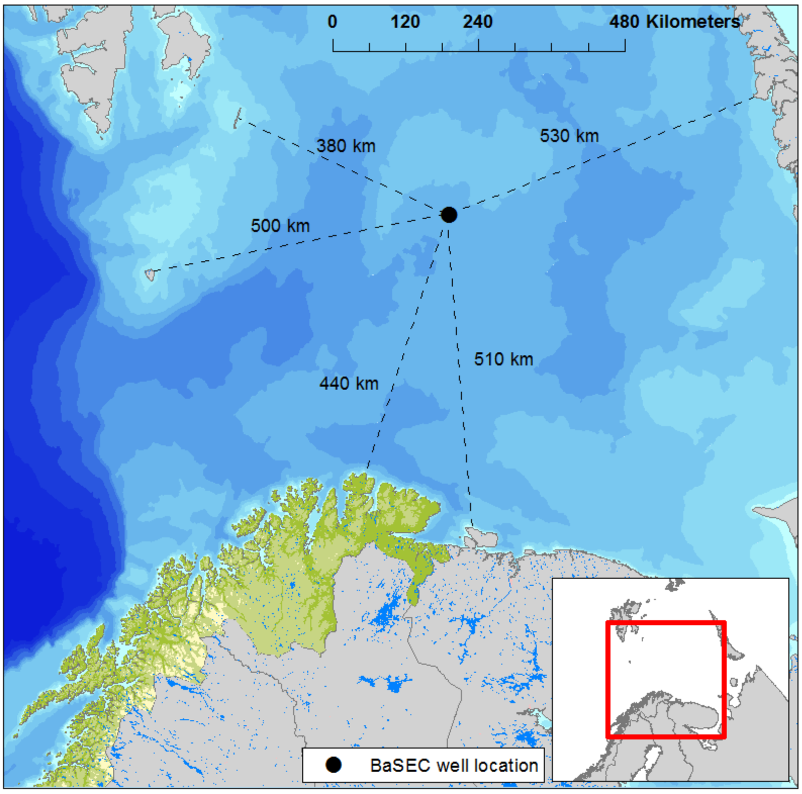

Figure 1-2 *Distances to nearest land areas from the well location in block 7435/9.*

Table 1-1 *Input applied in the environmental risk analysis.*

Blowout location	74,375° N; 35,833° E
Analysis period	Annual, presented as four seasons (spring (March – May), summer (June – August), autumn (September – November) and winter (December - February))
Water depth	228 m
Shortest distance to shore	Ca. 380 km (Hopen)
Fluid type (reference fluid)	Skrugard Crude Oil
Crude oil density	871 kg/m^3
Rates used in oil drift for environmental risk analysis	Topside: 800 Sm^3/d, 1600 Sm^3/d, 2200 Sm^3/d, 3500 Sm^3/d, 5000 Sm^3/d Subsea: 400 Sm^3/d, 1000 Sm^3/d, 1300 Sm^3/d, 2100 Sm^3/d, 4000 Sm^3/d
Durations used in oil drift for environmental risk analysis	2, 5, 14, 35 and 84 days (time used to drill relief well)
Type of scenarios	Topside and subsea blowout
Selected VEC species/populations	• Pelagic and coastal seabirds • Marine mammals in the coastal Barents Sea area • Ivory gull following the dynamic ice edge • VEC species following the Polar front • Gls-logger data for Common Guillemot • Coastal habitats

2 DEFINED SITUATIONS OF HAZARD AND ACCIDENT (DSHA)

Incidents with the greatest potential to harm the surrounding environment are uncontrolled releases of oil from the well during drilling (blowouts). For the purpose of this analysis a blowout scenario from an exploration well in block 7435/9 has been defined (Solberg, 2015). Blowout probability, flow rates and durations are quantified for application in the environmental risk assessment, and are further described in the following sections.

2.1 Blowout scenario

The potential blowout scenarios are described in (Solberg, 2015). A blowout during drilling may occur if a reservoir is penetrated while well pressure is in underbalance with the formation pore pressure, followed by a loss of well control. The blowout release path may be through open hole, drill pipe and annulus, each with a corresponding probability.

The overall blowout frequency is based on historic data gathered from the SINTEF offshore blowout database (Lloyd's Register Consulting, 2015). The blowout frequency of a wildcat exploration drilling with oil as expected fluid is $1.41*10^{-4}$ per well (Solberg, 2015). This frequency is further used in the risk calculations.

As the drilling rig used in the assessment is a semi-submersible rig, the probability distribution between surface and seabed release scenarios is set to 25 % and 75 % (Solberg, 2015).

2.2 Rates and durations

For this analysis, oil drift simulations are modelled for a set of combinations of rates and durations, as given in Table 2-1. Oil flow rates were calculated by Statoil (Solberg, 2015). The weighted rate for a topside blowout is calculated to 2735 Sm^3/day, whereas the weighted rate for a subsea blowout is 1730 Sm^3/day. The weighted durations, based on the modelled durations and their respective probabilities, are 10.5 days (topside) and 18.6 days (subsea).

Table 2-1 *Blowout rate and duration distribution for a blowout during an exploration drilling at block 7435/9 (Solberg, 2015).*

Release location	Probability	Oil flow rate [Sm^3/day]	Probability for rates	Durations (days) and probability distribution				
				2	5	14	35	84
Topside	25 %	800	10.0	66.4 %	14.4 %	9.0 %	2.7 %	7.4 %
		1 600	10.0					
		2 200	35.0					
		3 500	35.0					
		5 000	10.0					
Subsea	75 %	400	10.0	49.4 %	15.7 %	13.7 %	6.0 %	15.3 %
		1 000	10.0					
		1 300	35.0					
		2 100	35.0					
		4 000	10.0					

3 OIL SPILL TRAJECTORY MODELLING

In the following chapter oil type characteristics, oil spill trajectory modelling methodology and limitations, data processing and results are addressed.

3.1 Oil characteristics

Skrugard crude oil is chosen as reference oil type in the assessment. The oil characteristics are gathered from the oil weathering study for the oil type, carried out by SINTEF in 2012 (Øksenvåg, 2012).

Skrugard oil is a highly biodegraded, naphthenic oil with a medium density and a low content of wax and asphaltenes compared to other Norwegian crude oils. Spilled at sea, the oil temperature will rapidly be lowered to the ambient water temperature. In high sea conditions the oil is predicted to have short life expectancy at the sea surface due to evaporation and natural dispersion (~48 hours), but it may be more persistent in calmer weather (>5 days).

Some of the key characteristics for Skrugard crude oil are presented in Table 3-1.

Table 3-1 *Key characteristics for Skrugard crude oil.*

Parameter	Value
Oil density [kg/m^3]	871
Maximum water content at 5/10 °C [volume%]	80
Viscosity, fresh crude at 5 °C (10 s^{-1}) [cP]	32
Wax content [weight%]	1.89
Asphalt content [weight%]	0.05

3.2 Methodology

The oil drift model utilized is the SINTEF OSCAR (Oil Spill Contingency And Response) model version 6.2. OSCAR is a three-dimensional model calculating and recording the distribution, as mass and concentrations, of hydrocarbons on the water surface, in coastal habitats, in the water column and in sediments. The simulations are performed in 3×3 km grid cells with a detailed shoreline/coastal habitats (Resolution: 1:50 000). The results from OSCAR are presented in three physical dimensions, in addition to time (Johansen, 2006).

The model contains databases supplying water depth, sediment type, ecological habitat, and coastal habitat type, as well as an oil database supplying the physical and chemical parameters required by the model.

The model allows multiple release scenarios, each with a specified beginning and end. This allows time-variable releases at a given location, as well as throughout the study area.

For subsurface releases (e.g. blowouts from seabed or pipeline leakages), the near field part of the simulation is conducted with a multi-component integral plume1 model that is embedded in the OSCAR

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[1] A plume is here referred to plume of oil and gas, which is an elongated “cloud” of fluid and resembling a feather as it spreads from its point of origin.

model. The near field model accounts for buoyancy effects of oil and gas, as well as effects of ambient stratification and cross flow on the dilution and rise time of the plume.

The OSCAR model computes surface spreading, slick transport, entrainment into the water column, evaporation, emulsification and coastal habitat interactions to determine oil drift and fate at the surface. In the water column, horizontal and vertical transport by currents, dissolution, adsorption, settling and degradation are simulated. Variations in solubility, volatility and other weathering characteristics of different oil components are accounted for by representing the oil in terms of a number of pseudo-components.

OSCAR may compute oil weathering from crude assay data, although more reliable results are produced if the target oil has been subject to a standardized set of laboratory weathering procedures established by SINTEF. Alternatively, the model may use oil weathering properties of oil types for which data already exists, selecting the oil type in the database with the best match regarding its composition.

Both single spill scenarios and stochastic scenarios with variable start times can be simulated. In the stochastic simulations, a specified number of scenarios are simulated subsequently in one run. The set of scenarios to be run may be specified either by selecting the number of scenarios to be simulated within a specified time period (single year statistics), or by specifying the number of scenarios to be run each year in a specified season (multiyear statistics). In order to provide data for computing oil drift statistics, certain oil drift parameters are accumulated for each scenario in each impacted grid cell. These results are eventually used to calculate the probability of impact in any given cell. In this context, impact is defined as exceeding of a predefined threshold oil concentration. The results are expressed as hit probabilities and presented in maps for the different environmental compartments (sea surface, water mass and coastal habitat).

OSCAR accepts input both as two- and three-dimensional current data from hydrodynamic models, and single point or gridded wind data from meteorological models. In this study current data collected in the period 1998-2005 with a resolution of 4×4 km is utilized. The dataset is produced by Institute of Marine Research (IMR) and further processed by SINTEF. It contains both surface and water column currents. Historical wind data is provided by The Norwegian Meteorological Institute (MI) in 75×75 km resolution and three hours sampling intervals.

Due to the location of the “BaSEC well” it is chosen to incorporate a dynamic gird with daily mean ice concentrations for the period 1998-2005 from the Nordic Seas 4 km numerical hindcast archive (SVIM, ftp://ftp.met.no/projects/SVIM-public/SVIMresults) in the oil drift modelling. The data is imported to OSCAR from a NetCDF-formate. This dataset is used in the modelling to take into account possible effects of sea ice within the influence area after a spill from the well. Sea ice may affect the general weathering of the oil, the spread of oil at the sea surface, evaporation and down-mixing, but also how the oil moves in different ice concentrations. OSCAR uses an algorithm for oil spreading in partially ice covered waters, where for instance ice concentrations > 30 % will have a great impact on oil movement and weathering. The modelling is performed in alignment with the current recommendations in the guideline (Norsk olje og gass, 2014).

One statistical simulation will comprise a large number of spills with a specified spill rate and duration. The start time of simulations for the spills are distributed evenly throughout the period of years for which wind data are available. The number of spills to be simulated in one statistical run must be sufficiently large to provide a basis for reliable oil drift statistics on a seasonal basis (spring, summer, autumn and winter). The actual number of required simulations will depend on the duration of each spill, e.g. in order to cover the normal variability of wind and current data within the time window covered by the dataset. More simulations will be required for spills with short durations than for spills with long durations.

3.2.1 Model limitation and requirements for input data

Any model will necessarily represent a simplification of an actual oil spill, which means that there will be some discrepancies between the model predictions and the actual oil spill. However, at the same time, OSCAR can also help to make it easier to identify and understand the general trends and phenomena in the processes under study. This sub-chapter points out some of the most important known simplifications and assumptions in OSCAR. In addition, it outlines the uncertainties resulting from the model's structure as well as the layout of the simulation and the input data used.

The modelling of processes that remove pollutants from the modelled system is particularly interesting since it has a great effect on the extent of environmental damage following a spill. Oil in OSCAR is removed by means of evaporation, natural dispersion and possibly mechanical recovery. Furthermore, the oil can, to a certain extent, be immobilized on the beach/coastal habitats and in the sediments. Due to efficiency considerations, the settled oil is not followed in stochastic simulations. Oil on the beach degrades both in reality and in the model, however at a lower rate than for oil entrapped in the water column. Oil can be transported out of the modelled area, however the model calculations are normally set up based on the worst-case scenario and then only a small proportion of the total discharge is affected. In addition to degradation the natural dispersion and hence dilution of oil in the water column represents an important source for reducing the effect of discharged oil over time, (Johansen, 2010).

OSCAR is a particle-based model, where oil and chemicals in the model are represented as a set of particles. Each particle has a number of properties that change during a simulation. This includes general properties such as the position, mass and physical extension of a particle, however also properties related specifically to the oil drift modelling, e.g. viscosity, water content, chemical composition and water solubility.

In OSCAR, there are three main types of particles. These represent, respectively, substances which are dissolved in the water, droplet clouds in the water column as a result of chemical or natural dispersion and oil on the sea surface.

A simulation consists of a number of time steps where the particles' properties change:

- The particle’s position changes as a result of wind and currents acting on it.
- The particle’s mass and chemical composition changes as a result of evaporation, biodegradation, and exchange with droplet clouds and surface slicks.
- Water uptake and viscosity changes as part of a complex weathering process.

In addition, the particles change from representing droplet clouds to representing surface slicks and vice versa. Droplet clouds can rise to the surface as a result of the oil's buoyancy, and surface slicks can be mixed down in the water column as a result of wind-induced waves and turbulence.

Spilled oil at sea will give rise to a series of complex processes, and despite OSCAR being a very sophisticated model there are still processes that are not taken into account. Processes not included in OSCAR include Langmuir currents on the sea surface, in-detail modelling of wave-induced turbulence, and interaction with organic and inorganic particles in the water column. Furthermore, photo-oxidation, which can have a significant effect on the stability of emulsions, is not clearly addressed in OSCAR; however, it is to some extent represented by the UV light used in laboratory experiments aiming at describing the weathering process of the oil modelled. Under normal circumstances these shortcomings will only have a marginal effect on the results. However, in some instances the model will fail to produce a trustworthy prediction of oil drift and weathering. This applies for instance to major discharges, discharges of particularly long durations or at subnormal weather conditions.

Finally, as with any simplification of a complex and on-going process, a particle-based model will be sensitive to the chosen resolution. The more particles utilized in the calculations, the greater the potential is to create realistic simulations, given the utilized current, wind, water depth and coastal grid data. More particles, however, also mean more resource-intensive calculations, and the choice of resolution will be a trade-off between available computing resources and the benefits of increasing the resolution further. In this analysis a standard set up of 2500 particles has been utilized, based on in-house experience and rendering a solid foundation for the statistical analysis.

3.2.2 Processing and generation of results

Based on the stochastic oil spill simulations modelled with OSCAR, statistical parameters (e.g. surface hit probability and oil concentration) are calculated in predefined 10 × 10 km grid cells with a post processor.

Oil drift statistics for open sea are presented as mean values of actual parameters. Each time an oil particle enters a new grid cell, the pertinent parameters and counters for the specific grid cell will be updated. After all release scenarios have been simulated, the appropriate statistics for each grid cell, including landfall and influence area are computed.

The statistical parameters computed in each grid cell and reported are:

- **Hit probability** in each 10 × 10 km grid cell, defined as the relative number of simulations in which a particle, representing surface oil, has hit the grid cell. The influence area is defined as the area with a hit probability of at least 5 % for a minimum of 1 tonne of oil in a 10×10 km grid cell. The results are presented as the area of *expected* (≥50 % hit probability) and *not expected* (5-50 % hit probability) oil polluted given a spill.
- **Average amount of oil on the sea surface** in each 10 × 10 km grid celll. The oil mass in a sea surface area is time averaged by calculation, per simulation. The average numbers are based on all the simulations for each scenario (combination of rate and duration). The weighted results are based on each scenario and their individual probability.
- **Average minimum arrival time** in each 10 × 10 km grid cell. The time it takes for the first oil particle to enter a defined shoreline grid cell. The *average* results are based on all simulations and scenarios (combination of rate and duration) and their individual probability.
- **Water column concentrations** in each 10 × 10 km grid cell, are defined as the maximum average concentration over the simulation period and based on all simulations. Oil concentrations are given as total hydrocarbon (THC), i.e. both the dissolved fraction and oil droplets. The highest predicted concentration in the water column is conservatively considered representing the entire water column (from surface to seafloor). The influence area is defined as the area with a total hydrocarbon concentration of at least 100 ppb.
- **Sea surface oil for single simulations** is presented at different time steps for illustrative purposes and to further explore the potential overlap between ice and oil drift. The single simulations represent a topside blowout with 14 days duration and the highest blowout rate in the spring season.

Modelling start date defines which season a specific simulation will belong to:

- **Spring** (March-May),
- **Summer** (June-August),

- **Autumn** (September-November) and
- **Winter** (December-February).

Note that the export routine in OSCAR re-gridding the modelling results from 3 × 3 km cell to 10 × 10 km cells contributes to conservative estimates of the time average oil mass at the sea surface.

3.3 Oil drift modelling results

The oil drift modelling results given a topside or subsea blowout from the BaSEC exploration well is presented in the following subsections. The results are presented seasonally.

3.3.1 Hit probabilities

The oil hit probabilities are modelled for the blowout scenarios described in Chapter 2. In Figure 3-1 the modelled results based on all blowout rates and durations weighted with the probability for each combination (see Table 2-1) are presented, both for topside and subsea blowouts, in each season. The results are presented as the area likely (*expected* - ≥ 50 % hit probability) and the area less likely (*not expected* – 5-50 % hit probability) to be polluted given an oil blowout from the well.

Note that the influence areas do not show the extent of a single oil spill, but represents the area affected by more than one tonne of oil per 10 × 10 km^2 area in ≥ 5 % of all single simulations within each season.

To illustrated the actual expected extent of an oil spill the sea surface oil for one single simulation is presented at different time steps (4, 8, 12, 16 and 20 days). The single simulation represents a topside blowout with 14 days duration and the highest blowout rate in the spring season.

The results indicate somewhat larger influence areas for topside compared to a subsea release; however, the seasonal variations for each of the release location are minor. The single simulation shows surface oil to drift northwards the first four days followed a shift southwards (8 days). Maximum surface oil thickness is achieved at day 12 from which point thickness and range decrease and fully disappear at end of simulation (day 20).

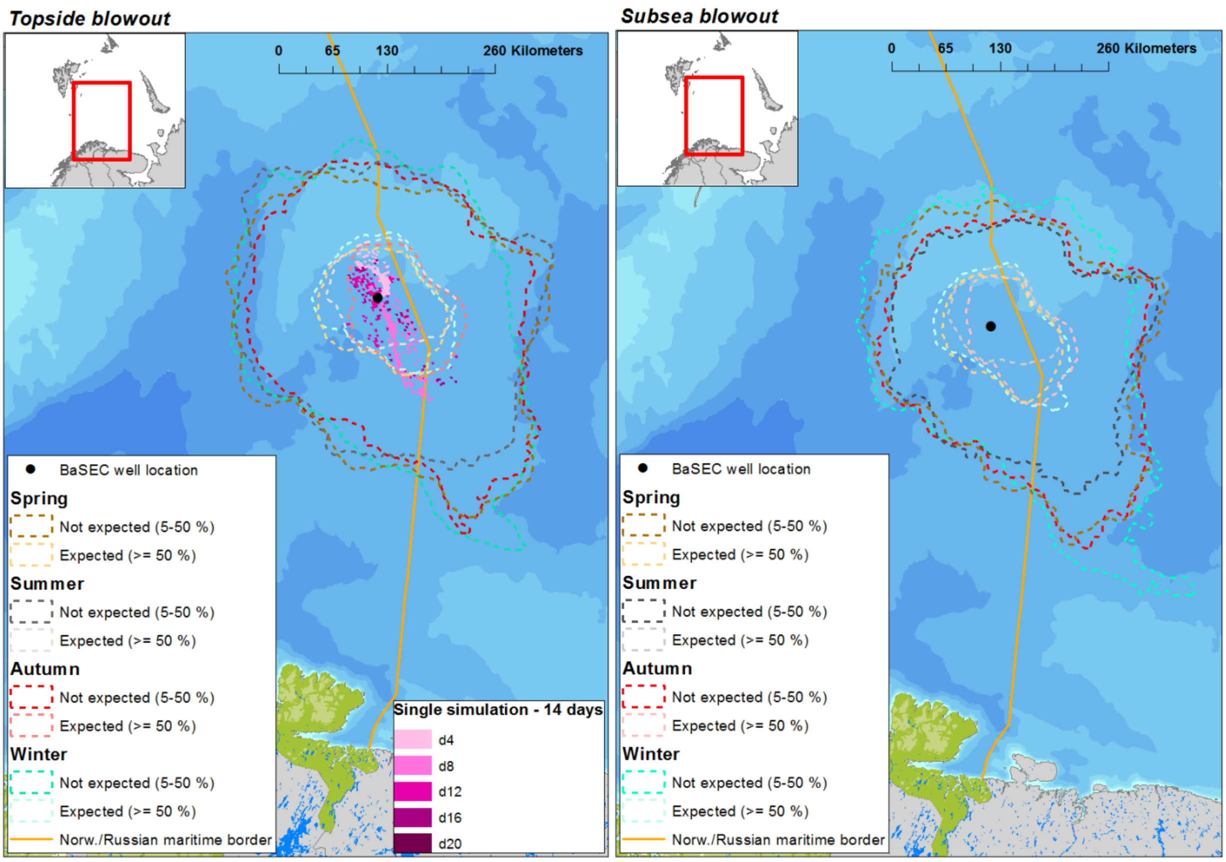


Figure 3-1 *Oil hit probabilities given a* ***topside blowout*** *(left figure) or* ***subsea blowout*** *(right figure) from the "****BaSEC well"*** *in each season (spring, summer, autumn and winter). The results are presented as the area expected (⩾ 50 % hit probability) and the area not expected (5-50 % hit probability) to be polluted given an oil blowout from the well, based on all release rates and durations and their individual probabilities. Note that the influence areas do not show the extent of a single oil spill, but the area hit by ≥ 1 tonne oil per 10 × 10 km grid cell in ≥ 5 % of all single simulations within each season. Spring figure includes single simulation results for different time steps (4, 8, 12, 16 and 20 days). The Norwegian-Russian maritime border is illustrated in the figures.*

3.3.2 Hit probabilities by mass categories

Time average oil mass per 10 × 10 km^2 area are presented in Figure 3-2 for topside blowout and Figure 3-3 for subsea blowout. Oil mass is divided into five categories;

- 1-50 tonnes,
- 50-100 tonnes,
- 100-500 tonnes,
- 500-1000 tonnes and
- >1000 tonnes.

The results are based on all release rates, durations and their individual probabilities. The oil masses are illustrated in the area likely to be oil polluted (*expected* - ≥50 % hit probability) and in area less likely to be oil polluted (*not expected* - 5-50 % hit probability). Within the *expected* area the oil is primarily distributed in the categories 50-100 and 100-500 tonnes per 10 x 10 km^2, whereas in the *not expected* area the oil is mainly in the range 1-50 tonnes per 10 × 10 km^2 area. Reduced surface oil during autumn and winter compared to the remaining part of the year is caused by the seasonal variations in weather conditions.

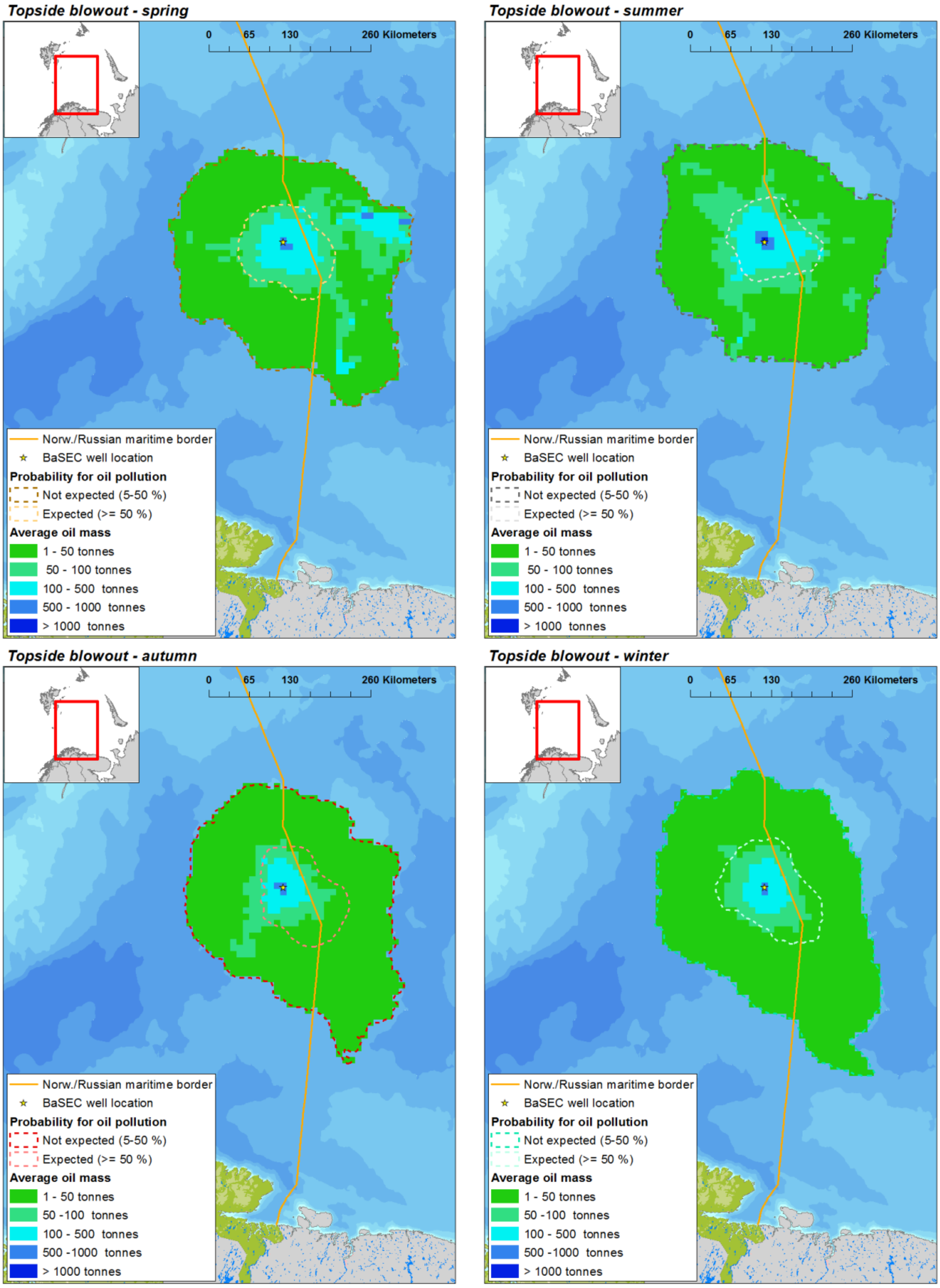


Figure 3-2 *Seasonal time average oil mass (tonnes) in 10 × 10 km grid cells given a **topside blowout** from the "**BaSEC well".** The influence areas are based on all release rates and durations and their individual probabilities. Note that the influence areas do not show the extent of a single oil spill, but the area hit by ≥ 1 tonne oil per 10 × 10 km grid cell in ≥ 5% of all single simulations within each season. The Norwegian-Russian maritime border is illustrated in the figures.*

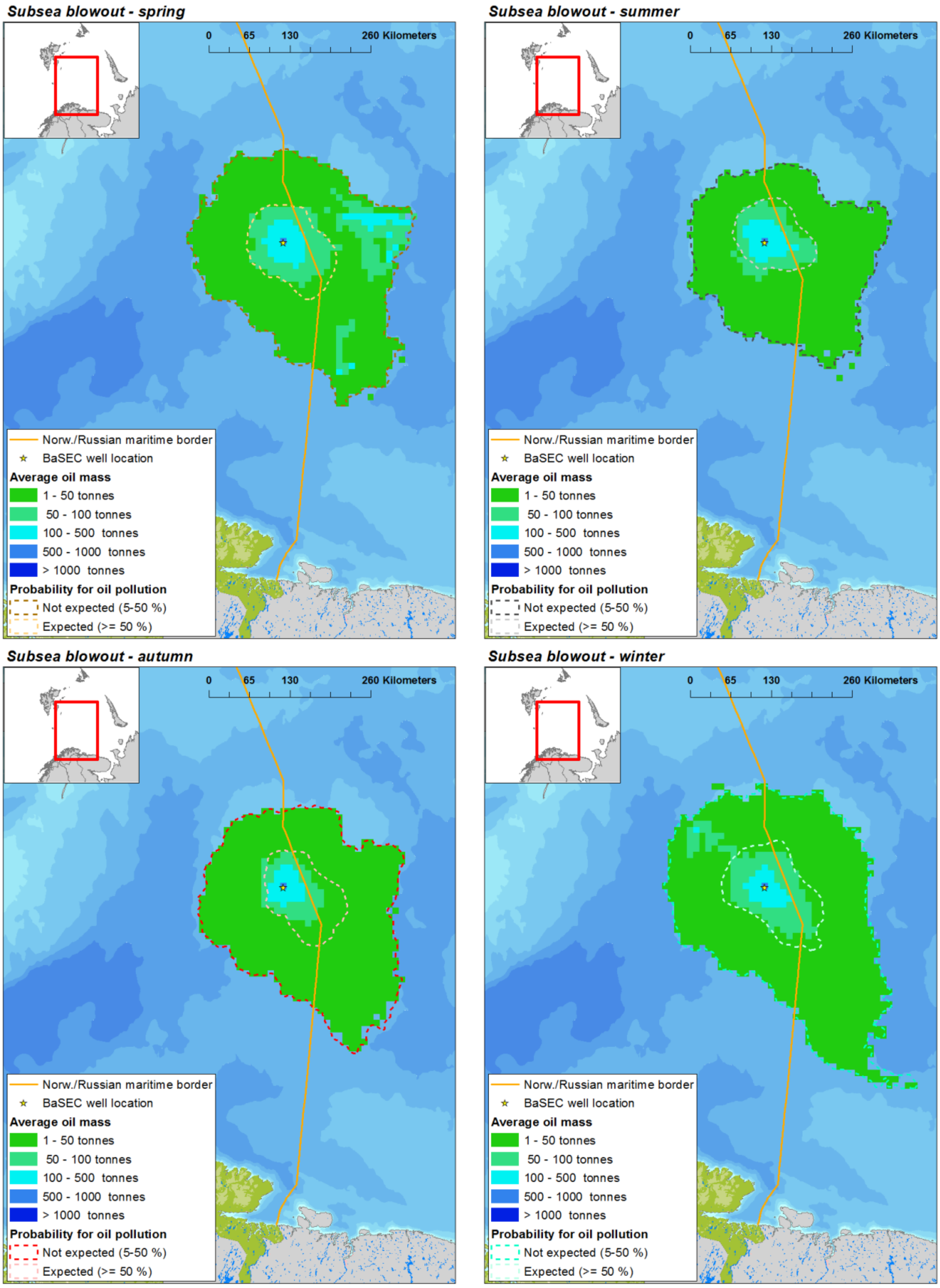
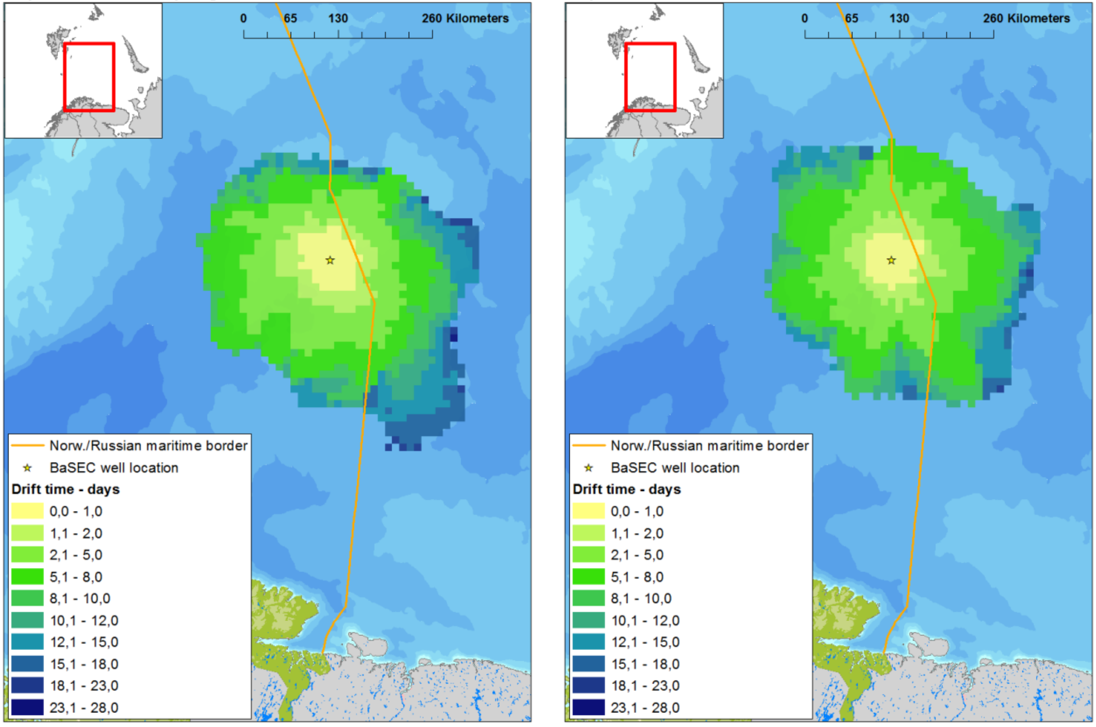


Figure 3-3 *Seasonal time average oil mass (tonnes) in 10 × 10 km grid cells given a* ***subsea blowout*** *from the "****BaSEC well"****. The influence areas are based on all release rates and durations and their individual probabilities. Note that the influence areas do not show the extent of a single oil spill, but the area hit by ≥ 1 tonne oil per 10 × 10 km grid cell in ≥ 5% of all single simulations within each season. The Norwegian-Russian maritime border is illustrated in the figures.*

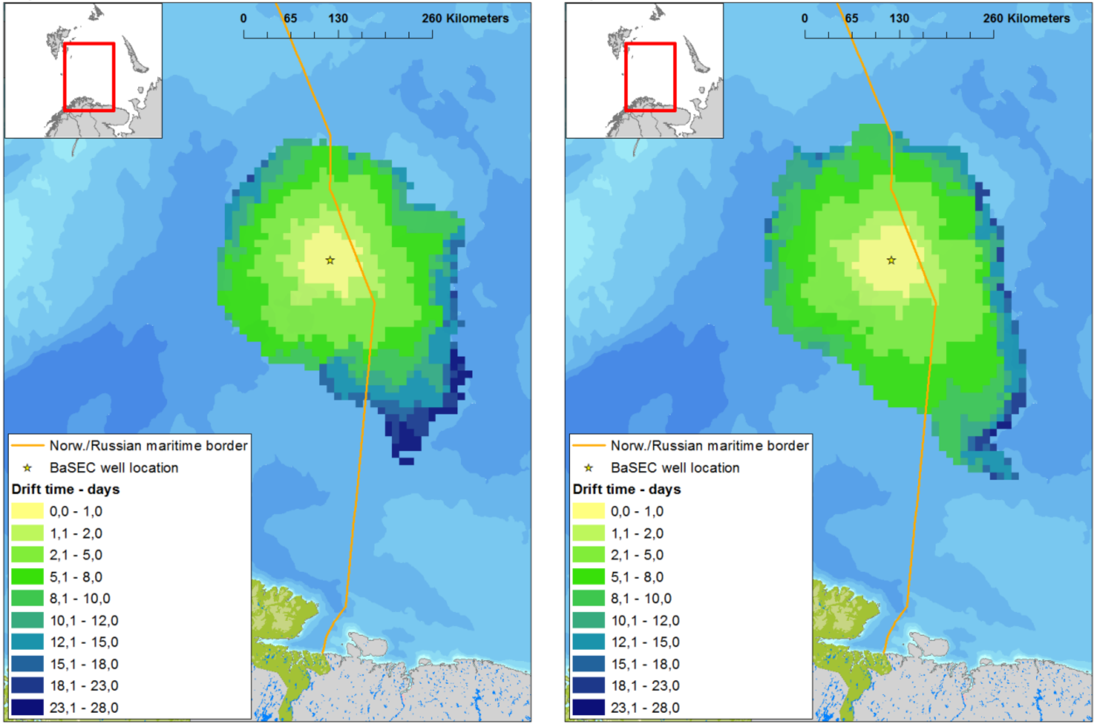
3.3.3 Arrival time

The average arrival time of oil to each affected 10 × 10 km area within the influence areas (≥5 % probability for ≥ 1 tonne oil per cell) is illustrated in Figure 3-4 (topside blowout) and Figure 3-5 (subsea blowout) in each season. The figures shows that surface oil from a blowout from the “BaSEC” well can reach the Norwegian/Russian maritime border within 1 day. The arrival time to this area is further explored in section 3.3.6.



Topside blowout - spring

Topside blowout - summer



Topside blowout - autumn

Topside blowout - winter

Figure 3-4 *Seasonal average minimum arrival time (days) of oil in 10 × 10 km grid cells given a* ***topside blowout*** *from the "****BaSEC well"****, based on all release rates and durations and their individual probabilities. Note that the influence areas do not show the extent of a single oil spill, but the area hit by ≥ 1 tonne oil per 10 × 10 km grid cell in ≥ 5% of all single simulations within each season. The Norwegian-Russian maritime border is illustrated in the figures.*

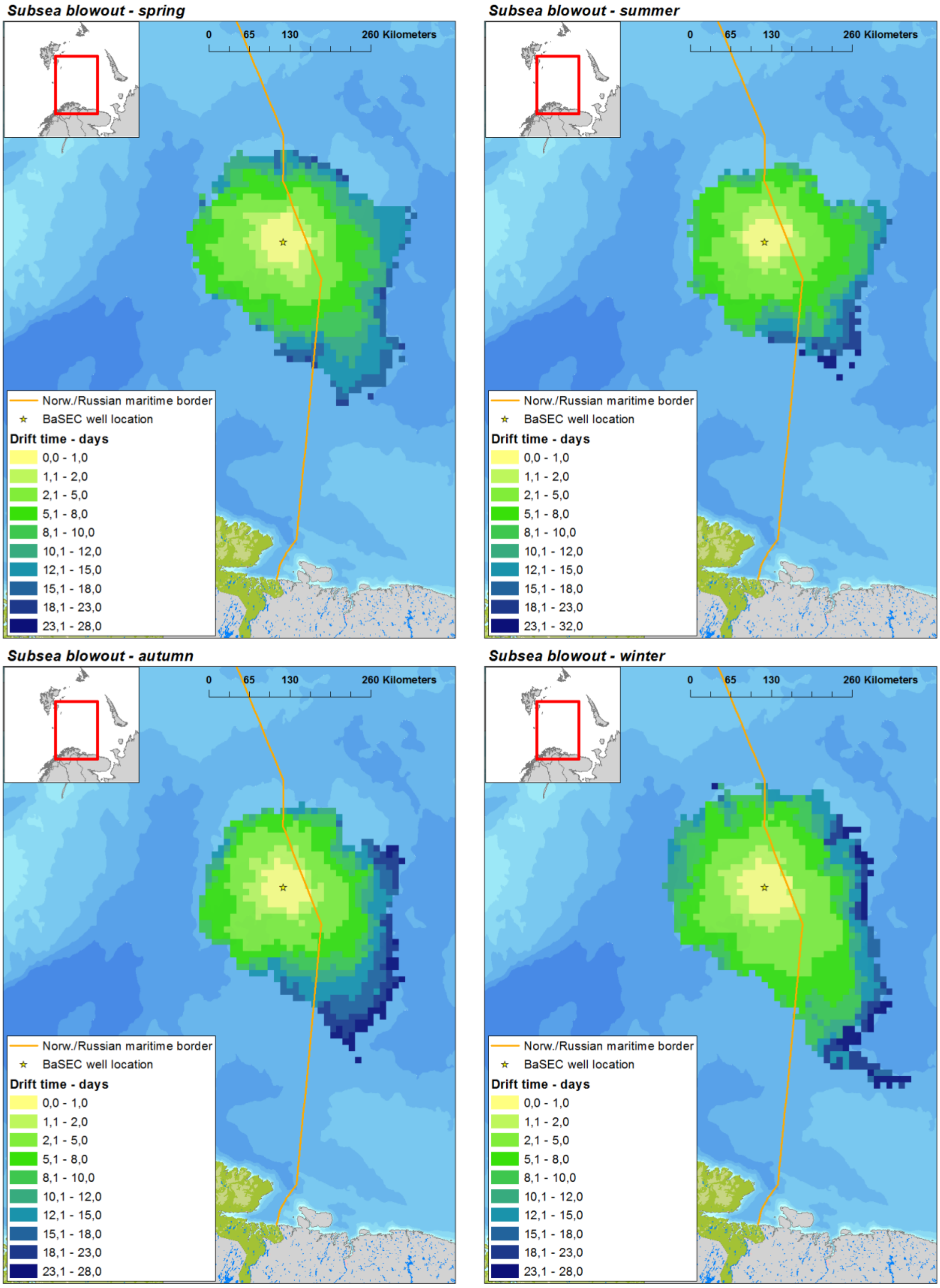


Figure 3-5 *Seasonal average arrival times (days) of oil in 10 × 10 km grid cells given a* ***subsea blowout*** *from the "****BaSEC well"****, based on all release rates and durations and their individual probabilities. Note that the influence areas do not show the extent of a single oil spill, but the area hit by ≥ 1 tonne oil per 10 × 10 km grid cell in ≥ 5% of all single simulations within each season. The Norwegian-Russian maritime border is illustrated in the figures.*

3.3.4 Water column concentrations

The results indicate that combined for all subsea simulations (weighted) the threshold value of 100 ppb is exceeded in one 10 × 10 km grid cell during spring season. Moving from weighted data to focus exclusively on the combination highest rate/longest duration the results are in total 45 different grid cells (10 × 10 km) with THC concentration above the threshold for effects on eggs and larva; 100 ppb. The absolute maximum concentration in one single cell is 386 ppb. This scenario is illustrated in Figure 3-6.

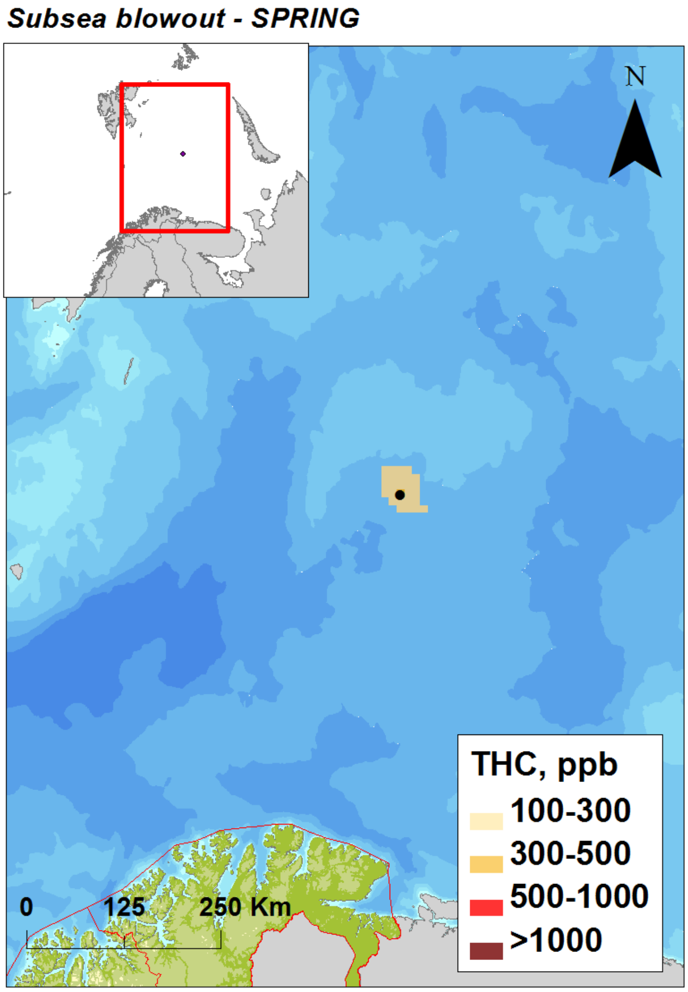


Figure 3-6 *Modelled total hydrocarbon concentration in water column after a subsea blowout from the BaSEC well with the highest rate and longest duration, during spring season. The output represents the scenario with potential for maximum impact.*

3.3.5 Hit probabilities – coastal habitats

Based on the weighted results, taking into account the individual probabilities for each combination of rate and duration, no coastal habitats have ≥5 % probability for being affected by more than 1 tonne of oil per 10 × 10 km^2 area. The same results are seen for the “expected”, but somewhat conservative, scenario; duration 15 days, and the largest blowout rate (5000 Sm^3/d), however increasing the duration to 35 days gives hits of one single grid cell in the mass category 1-100 tonnes in the spring season.

In a conservative setting; combining highest rate and various durations, the results show hits of one single grid cell in the mass category 1-100 tonnes in the spring season given 35 days duration. For the worst case scenario (highest rate/longest duration) the number of affected land grid cells increase to seven (in the spring), where one of the grid cells are affected by oil in the mass category 100-500 tonnes. The number of affected grid cells given the worst case scenario in the autumn season is four (all in the category 1-100 tonnes), and there are no grid cells with ≥5 % hit probability in the summer or winter.

The 95-percentile of all simulations is zero for shoreline in general and the defined “example areas” (see *Definitions and abbreviations*). The shortest arrival time to shore and the largest masses of stranded oil emulsion is given in Table 3-2 (in general) and Table 3-3 (specified on location). The simulation representing the 100-percentile resulted in a modelled mass of 1764 tonnes oil emulsion stranding at Svalbard south-east during spring. The absolute shortest arrival time to shore was modelled to 40.5 days, to the area of Svalbard south-east during spring. The overall probability (based on all simulations) for oil drifting to shore is less than 0.5 %. The seasonal variations are limited; however in the summer there is no probability for oil drifting to shore. On an annual level the overall probability for oil stranding is 0.3 %.

Table 3-2 *Largest stranded mass of oil emulsion and shortest arrival time to shore given a blowout from the BaSEC well (100-percentiles) given for each season. The given values are based on all simulations for both topside and subsea scenarios. The given oil masses and arrival times may origin from different oil drift simulations.*

Percentile	Stranded oil emulsion (tonnes)				Arrival time to shore (days)			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
100	1764	0	389	1127	40.5	n/a	71.3	73.6
95	-	-	-	-	-	-	-	-

Table 3-3 *Stranded mass of oil emulsion and shortest arrival time to shore given a blowout from the BaSEC well (100-percentiles) given for each season. The given values are based on all simulations for both topside and subsea scenarios. The given oil masses and arrival times may origin from different oil drift simulations.*

Example area	Stranded oil emulsion (tonnes)				Arrival time to shore (days)			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Hopen	0	0	389	146	n/a	n/a	71.3	88.1
Svalbard southeast	1764	0	0	1127	40.5	n/a	n/a	73.6

3.3.6 Oil drift into the Russian waters

The close proximity of Block 7435/9 including the “BaSEC well” to the Russian maritime boarder creates a high degree of likelihood for cross-boundary pollution in case of an oil spill from the well. Besides the oil drift calculations indicating amount of oil reaching the maritime borderline the topic is reflected upon in the Status document (DNV GL, 2015b) with emphasis on oil spill emergency preparedness challenges. The *time-average* oil masses along the Russian maritime border are illustrated in Figure 3-7. *Time-average mass* is calculated based on average oil mass in each 10 × 10 km^2 for the time periods that oil is present. The results from the scenario (weighted rate and duration) indicate that summer is the season with potential for most oil to pass the border mainly due to less dispersion (following calmer weather conditions).

The minimum average arrival time to the Norwegian-Russian maritime border is less than 1 day based on all scenarios (topside and subsea) (see Figure 3-4 and Figure 3-5). Marginal seasonal variations are observed, ranging from 14 to 17 hours. Winter is the season when the shortest arrival time is observed.

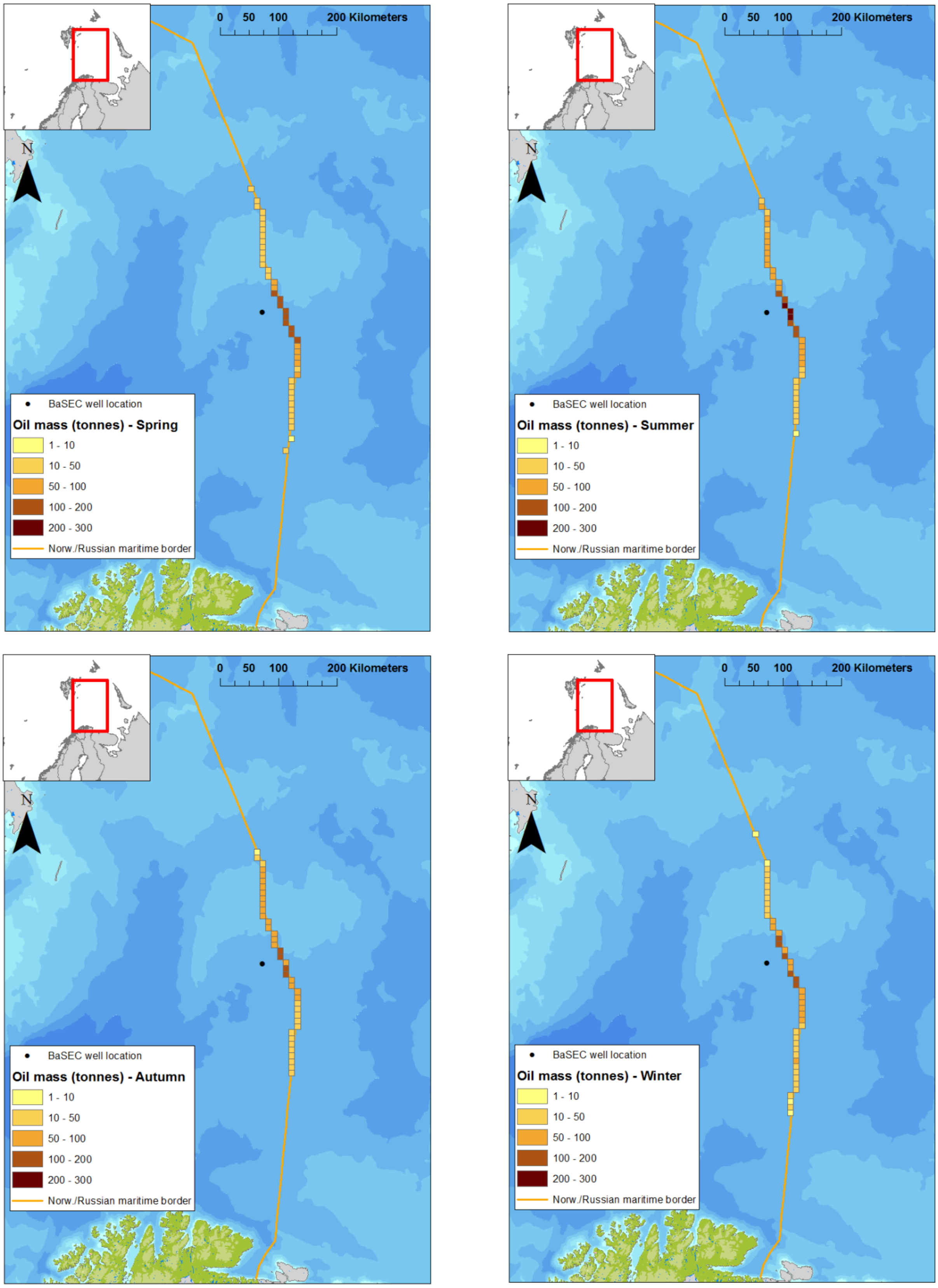


Figure 3-7 *Time-average oil masses (tonnes) crossing the Norwegian-Russian maritime border given a blowout from the BaSEC well using weighted rate and duration (2735 Sm^3/d / 9 days), for all seasons. NB: the hit probability is not taken into account in the results presented.*

3.3.7 Interactions with the marginal ice zone (MIZ)

The BaSEC well location is in an area in the Barents Sea which may be (partially) ice covered in periods of the year. Daily mean ice concentrations for the period 1998-2005 is incorporated in the oil drift model, which means that the presence of sea ice will affect the oil drift and distribution. The incorporation of dynamic ice data in the OSCAR model makes it feasible to get a better (compared to in the past when using static data) understanding on how the drift of sea ice and spilled oil interact, addressed by running single simulations matching oil drift and ice drift. Basing the conclusions merely on a study of overlap between the influence areas and “static” (statistical) pictures of the marginal ice zone at different times of the year would give an incomplete picture as the drift and spread of both oil and the sea ice at prevailing sea states should be taken into consideration.

The output from the single simulations indicates lower probability for overlap between oil and ice, as the same environmental/ weather conditions affect both surface oil and drifting sea ice. This means that one can expect a similar movement pattern for both sea ice and surface oil; when the oil drifts northward, so does the sea ice. An example of this case is shown in Figure 3-8, where oil and ice move north in the first three illustrations, and as the wind changes, both oil and ice are moving southwards (start date 27.03.2001).

In a scenario where the sea ice moves southward and covers the spill location before the spill has ended, oil in the ice zone may become a relevant issue. An example of the latter is illustrated in Figure 3-9 (start date 18.04.2003). In such a case, one might assume that environmental resources connected to the marginal ice zone, such as Ivory gull and a number of marine mammals, are most vulnerable.

According to the updated Management plan for the Barents Sea the *marginal ice zone* is defined as the area of ≥ 15 % ice concentration in more than 30 % of the time (Klima - og Miljødepartementet, 2015). This ice concentration is further used to evaluate the probabilities for oil entering the marginal ice zone after a blowout.

DNV GL has developed a tool (*Ice Mapper*) to map the occurrence of sea ice at different concentrations at different times of the year, based on statistical satellite data from the period 2003-2014 (University of Bremen). This tool is used in the evaluation of possible oil exposure in the marginal ice zone after a blowout from the BaSEC well. The results are shown as frequency for ice concentrations > 15 % and > 50 % in each month from January-June in Figure 3-10 and Figure 3-11. Throughout the summer and autumn the ice is expected to retreat further north, before advancing once again with decreasing temperatures entering the winter season. The figures show that there is a 10-20 % probability for ice concentrations > 15 % within a 50-100 km range north of the BaSEC well location in the period January to March. In April-June the probability is reduced to < 10 %. For the higher ice concentrations (> 50 %) the results are similar in the period January-March, while decreasing rapidly in April-May, to no probability within the analysis area in June.

The possible interactions between oil and sea ice is further explored for specific 10 × 10 km^2 areas at release location and 50 km, 100 km and 150 km north of the release location. Ice concentrations in the areas selected at different time periods (from February-May 1999-2005) are matched in time with sea surface oil. The results are presented in Figure 3-12 and Figure 3-13. Figure 3-12 illustrates that ice concentrations exceeding 15 % at release location are primarily from February-March 2003 and 2004. Both 50 km and 100 km north of the release location there are registered two out of 117 simulations (< 2 %) with overlap between oil and ice concentrations > 15 %; 50 km north of the release point the simulation dates are 13.05.1999 and 20.03.2004, while 100 km north of the release points the simulation dates are 20.04.1999 and 21.03.2004. The average arrival time of oil to the marginal ice zone are given in Table 3-4, and varies from 14 days to 24 days. In a period of ice progressing southward, surface oil may be capsulated in the ice, and be transported with the ice over long distances, only to be released and contaminate new areas (DNV GL, 2015b). In the spring period (April-June) the sea ice is retreating and oil is less likely to be trapped in the ice cover. 150 km north of the release location there are only registered one simulation (24.05.2004) with oil hit probability, however this was at a time when the ice concentration was only 0.35 %. In conclusion, the generated data indicate that the probability of oil hitting the specified areas is most likely to take place when no ice is present.

The modelling results show that even spill scenarios related to a location as far north as the BaSEC well location give rather small probabilities for surface oil entering the marginal ice zone. However, hits can occur at certain times of the year (the period of maximum ice extent; February-March) or in years with particular low temperature profiles (e.g. 2003).The possible consequences of oil in the ice zone are further explored through analysis of population losses of *valued ecosystem components* connected to the ice zone (VEC, see sections 5.1 and 5.1.5.1 for definition and description of dataset). The results of these calculations are presented in section 6.1.2.

Table 3-4 *Average arrival time of oil to the marginal ice zone at a distance of 50 km and 100 km from the release location. See Figure 3-12 and Figure 3-13 for more information.*

Distance from release point (km)	Simulation date	Arrival time (days)
50	20.03.2004	14.0
	13.05.1999	24.0
100	20.04.1999	24.0
	21.03.2004	16.7

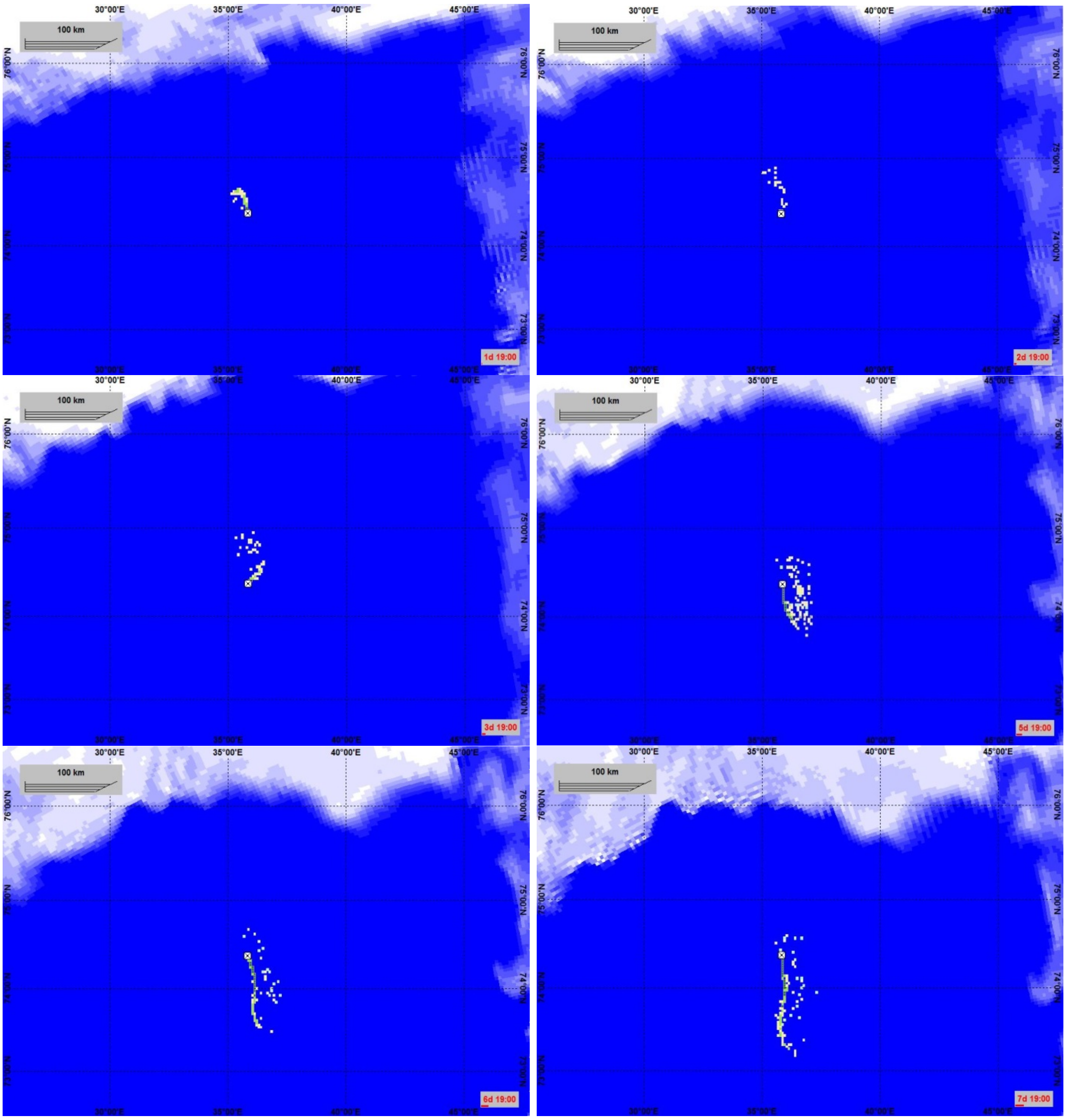


Figure 3-8 *Oil drift simulation with start date 27.03.2001, illustrated with corresponding ice data.*

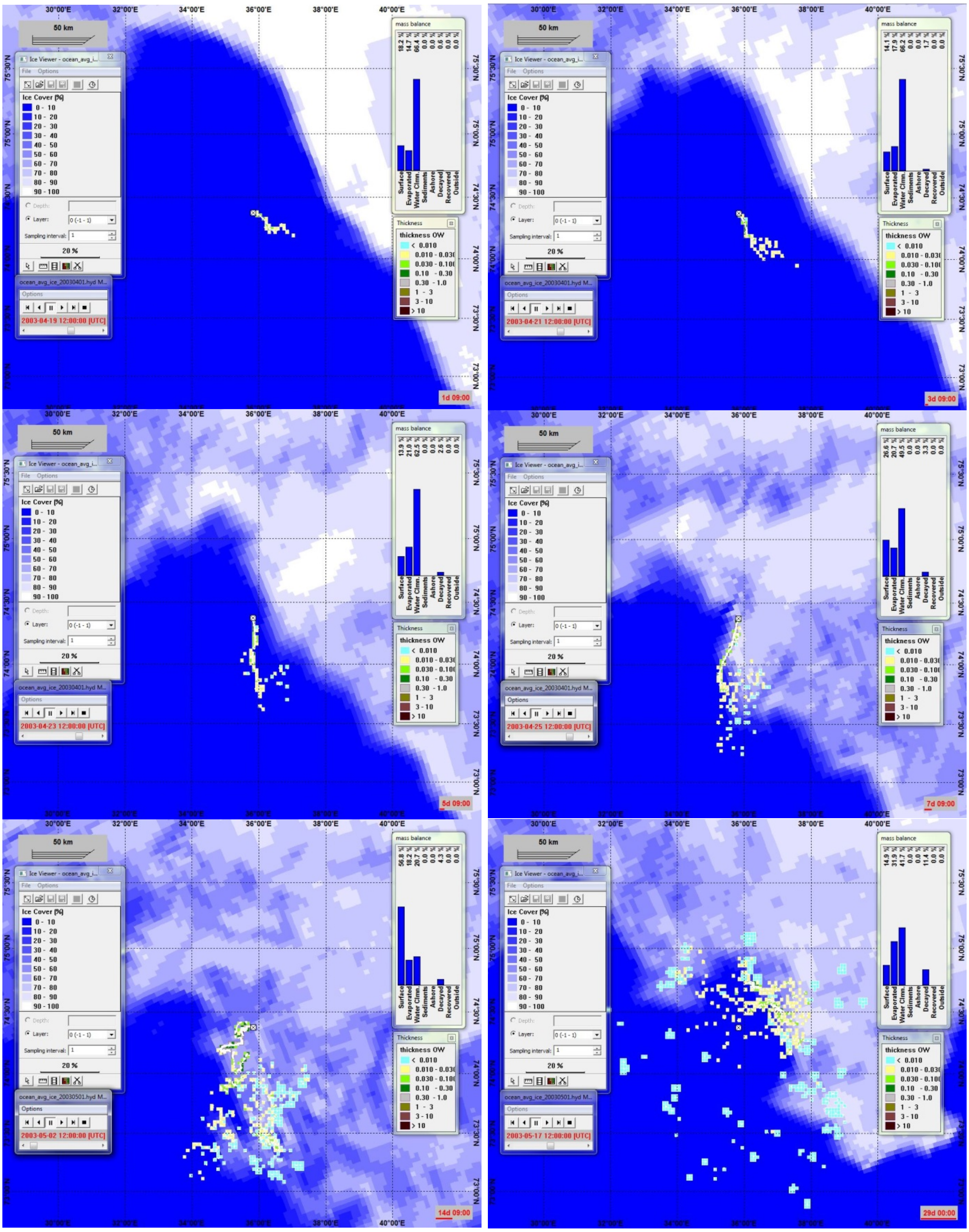


Figure 3-9 *Oil drift simulation with start date 18.04.2003, illustrated with corresponding ice data.*

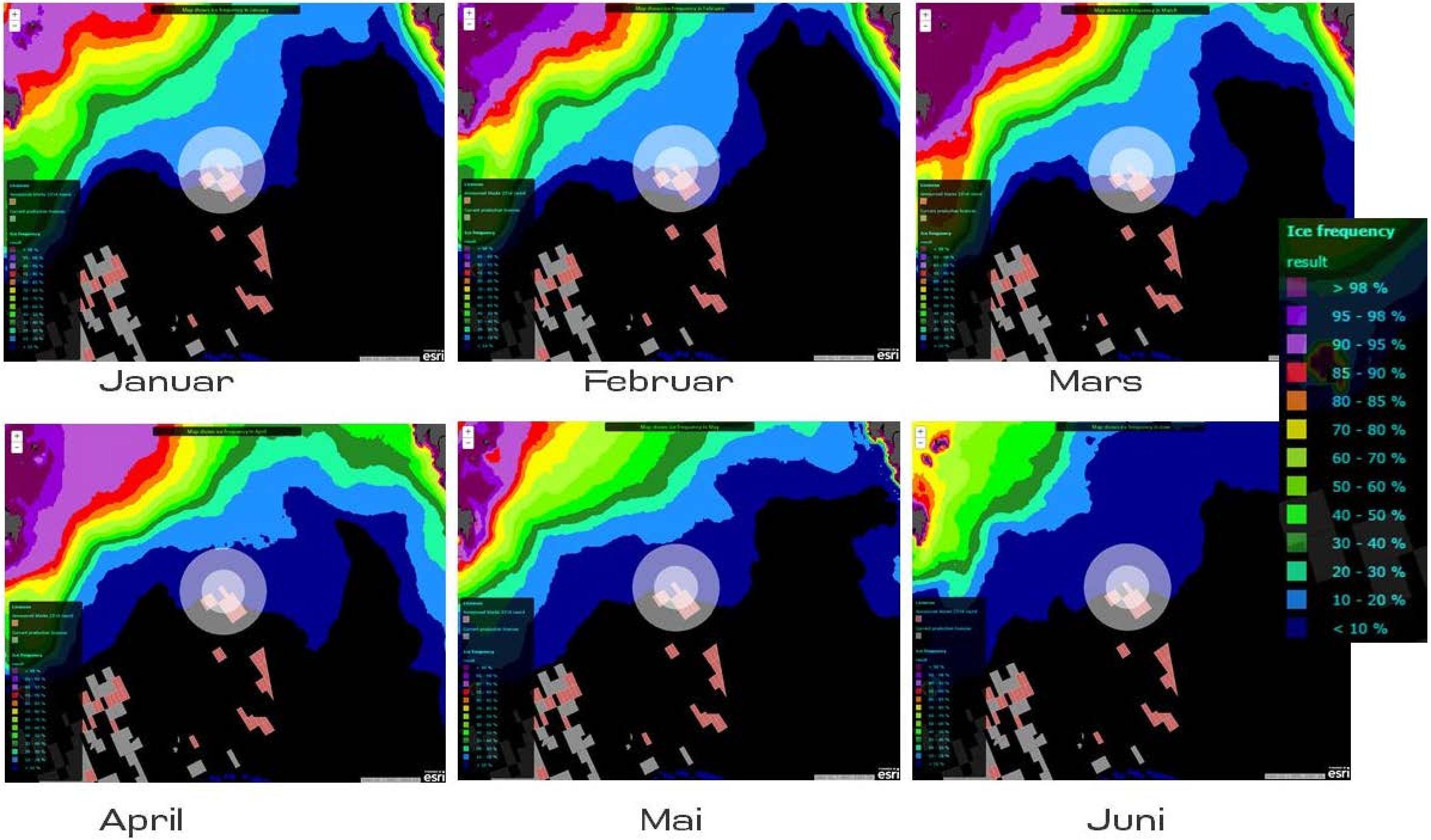
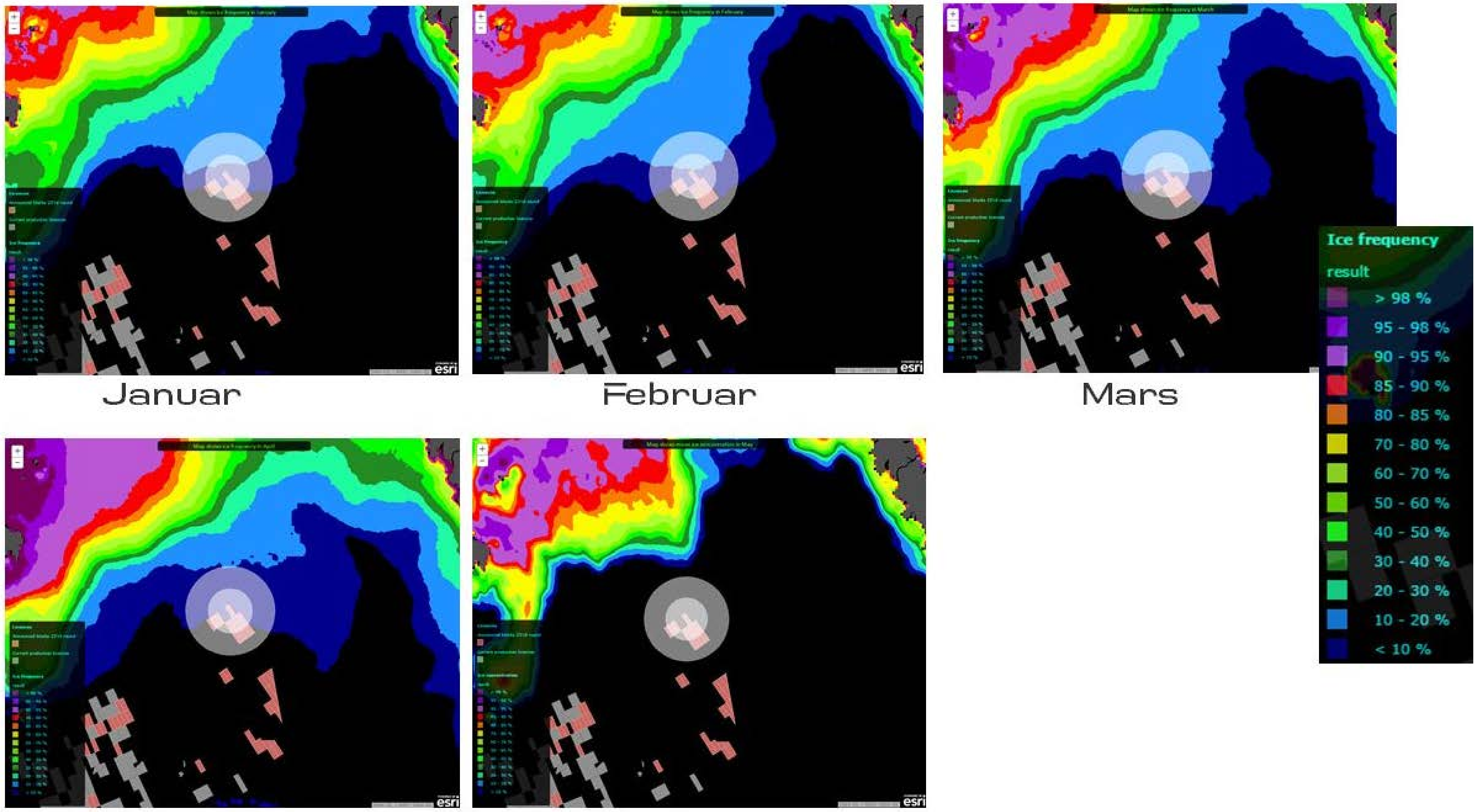


Figure 3-10 *Frequency for > 15 % ice concentration in each month from January to June, based satellite on data from 2003-2014 (University of Bremen). The BaSEC well location is centred in the light circles, with a 50 km and 100 km buffer zone surrounding it.*



Januar Februar Mars

April Mai Juni

Figure 3-11 *Frequency for > 50 % ice concentration in each month from January to June, based on satellite data from 2003-2014 (University of Bremen). The BaSEC well location is centred in the light circles, with a 50 km and 100 km buffer zone surrounding it.*

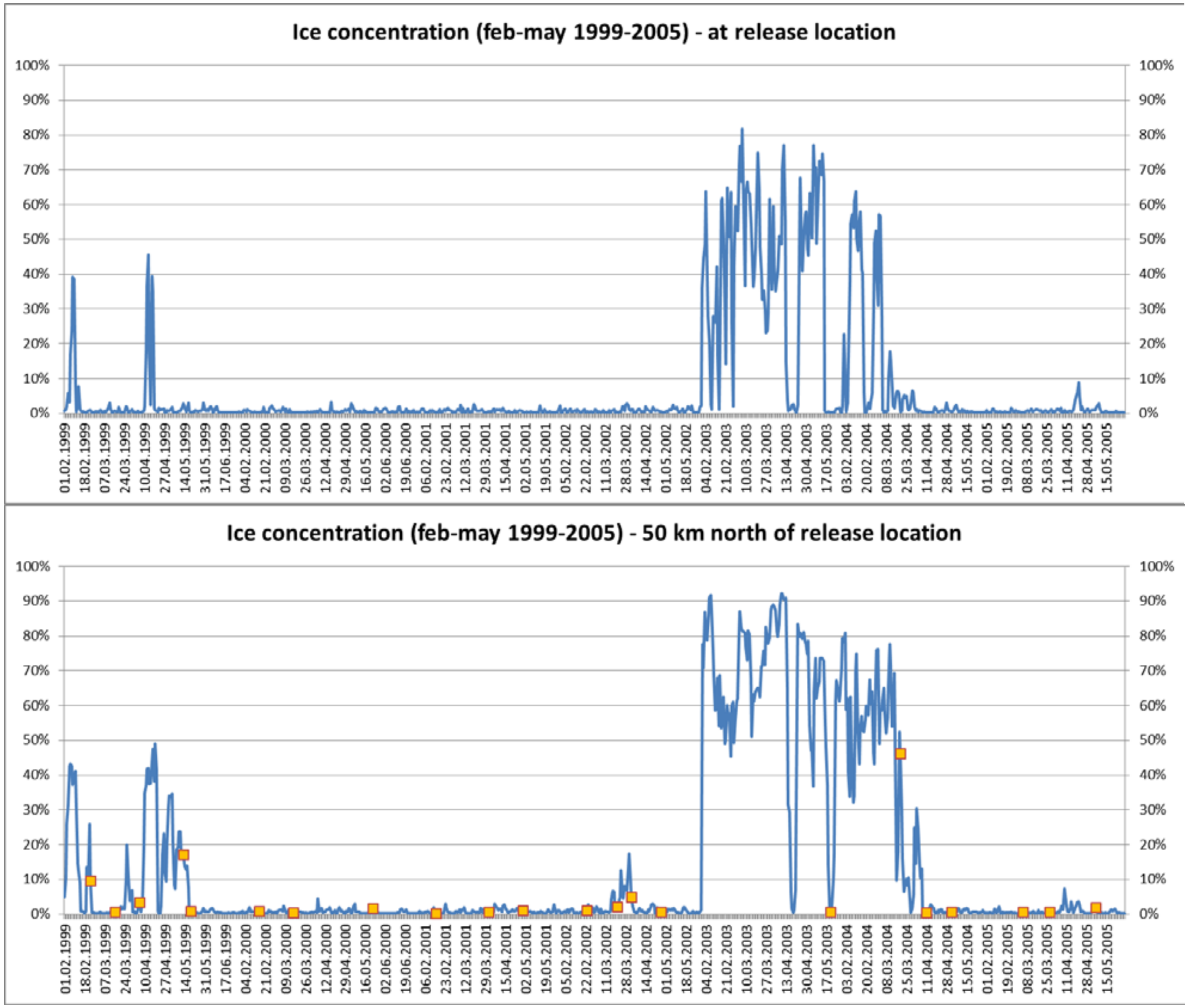


Figure 3-12 *Ice concentrations at the release location (upper figure) and 50 km north of the release location corresponding to the oil spill trajectory modelling in the period; February-May in 1999-2005. Simulations reaching the selected location (one 10×10 km grid cell) are marked with orange boxes.*

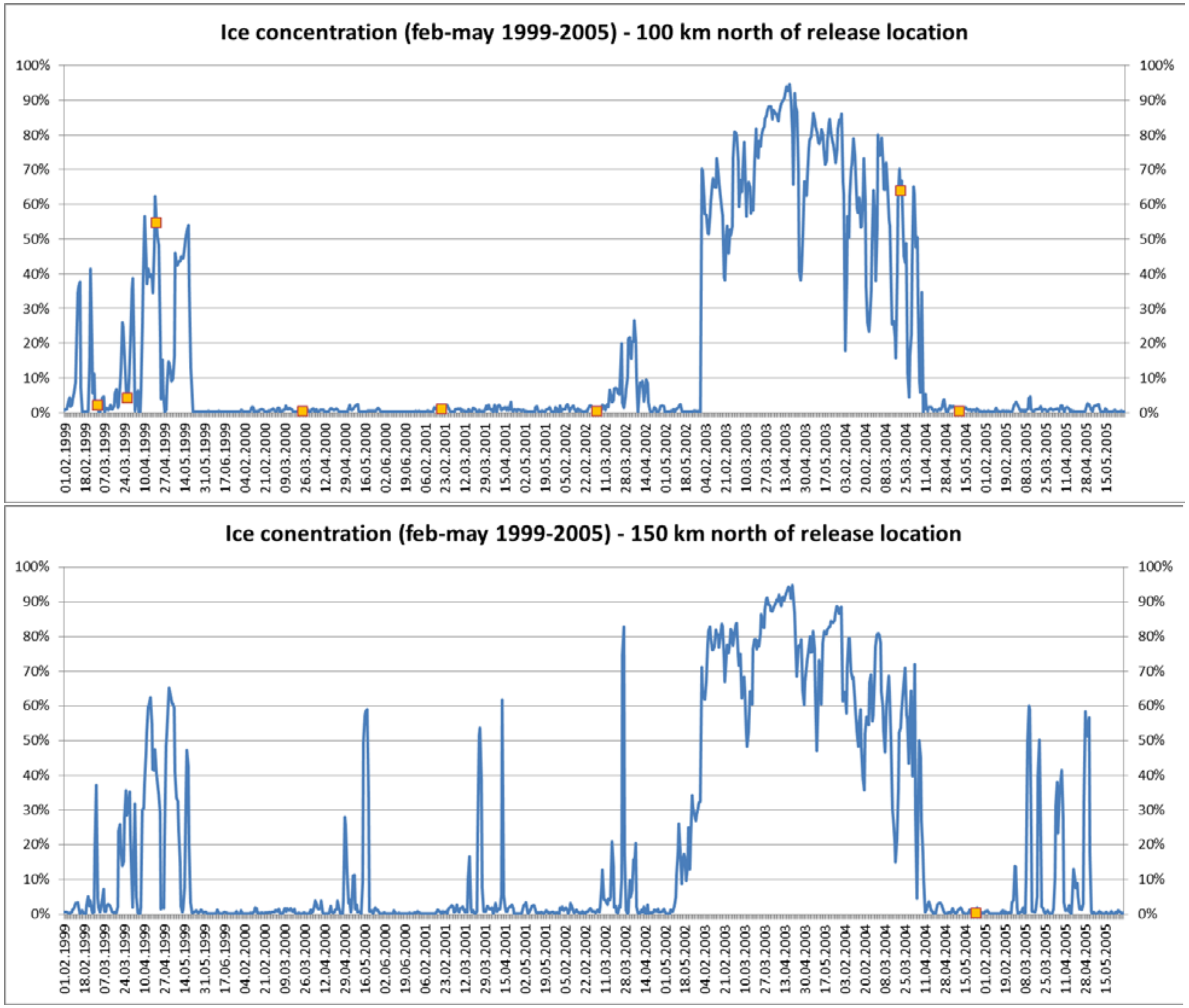


Figure 3-13 *Ice concentrations 100 km (upper figure) and 150 km (lower figure) north of the release location corresponding to the oil spill trajectory modelling in the period; February-May in 1999-2005. Simulations reaching the selected location (one 10×10 km grid cell) are marked with orange boxes.*

4 METHOD FOR ENVIRONMENTAL RISK ANALYSIS

Analysis of environmental risks is performed in steps according to the Norwegian oil and gas guideline for environmental risk assessments, (OLF, 2007b). For the BaSEC project, it has been chosen to conduct a damage-based analysis for the predicted most vulnerable environmental resources potentially affected by the planned activity. A summary of the methodology for environmental risk analysis is described below with focus on VEC populations (*valued ecosystem components,* see section 5.1). For a more detailed description it is referred to Appendix A and the guideline.

Based on oil drift modelling and the use of effect keys, the population loss for each VEC population is calculated (see Figure 4-1).

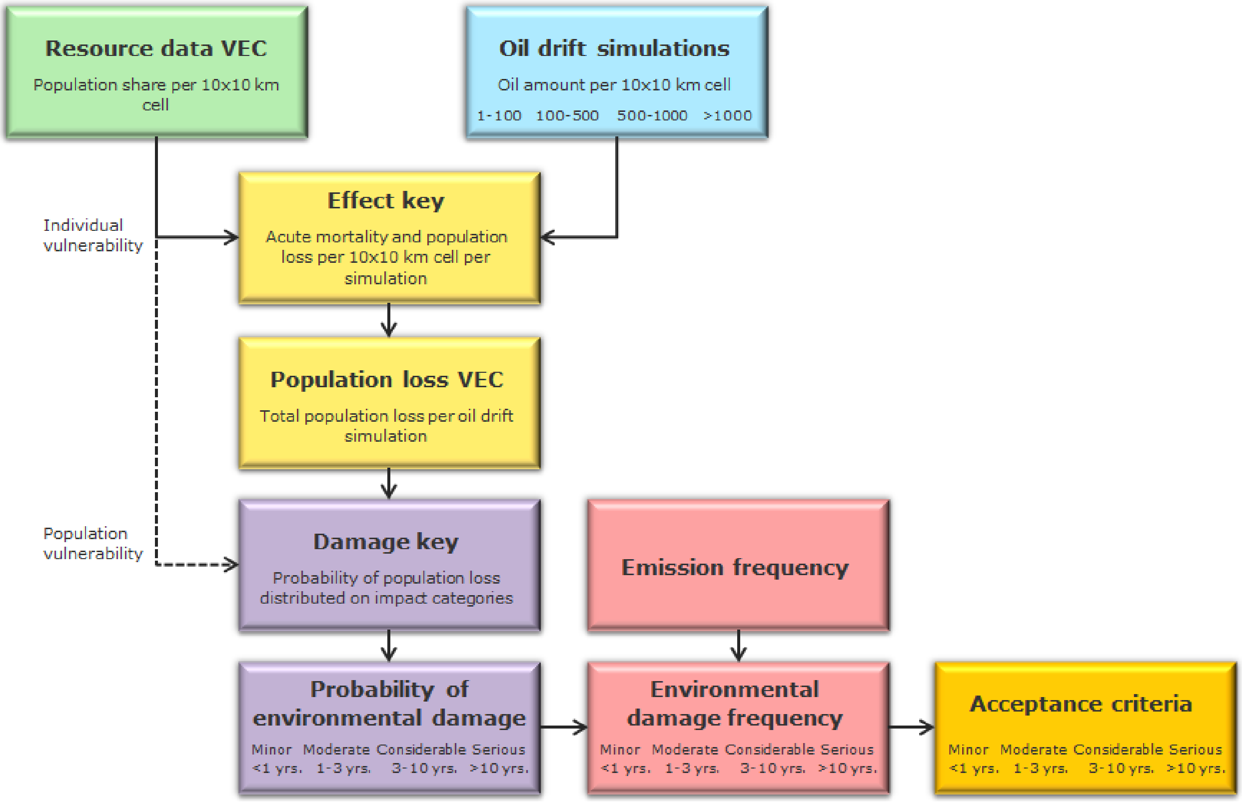


Figure 4-1 *Overview of the different steps when calculating the population loss and the environmental risk for VEC populations.*

Step 1 – Rescaled VEC population data, to match the oil spill cell size, is combined with each oil drift simulation. An effect key is used, indicating possible population loss in 10 ×10 km grid cell based on the amount of oil entering the area in each simulation (see Table 4-1). Different individual vulnerability to oil corresponds to different effect keys, whereas V1 indicates the least vulnerable species, V2 indicates moderate vulnerability and V3 indicates the most vulnerable species.

Table 4-1 *Effect key for estimating fraction of birds affected within a 10 × 10 km^2 area, given oil exposure (divided in four mass categories). Values are given for seabirds as an example.*

Oil mass in 10 x 10 km grid cell	**Effect key – Acute death rate**		
	Individual vulnerability for VEC seabirds		
	V1	**V2**	**V3**
1-100 tonne	5 %	10 %	20 %
100-500 tonnes	10 %	20 %	40 %
500-1000 tonnes	20 %	40 %	60 %
≥1000 tonnes	40 %	60 %	80 %

Step 2 – Population losses per 10 × 10 km^2 area are summarized and give a total population loss for each VEC population for each simulation. Population losses for the different oil drift simulations are categorized in 1-5 %, 5-10 %, 10-20 %, 20-30 % and more than 30 %. Population loss below 1 % is believed to have no significant effect on the population level, and is therefore not further considered.

Step 3 – It is used a damage key which ties a given population loss for the VEC populations to environmental damage. Environmental damage is expressed as the time it takes for a population to be restored to 99 % of the level before an event occurs (OLF, 2007b). As noted above, the vulnerability varies between species (and habitats) and the recovery time will be affected by this. The theoretical recovery time is divided into four categories, see Table 4-2.

- *Minor* (< 1 years),
- *Moderate* (1-3 years),
- *Considerable* (3-10 years) and
- *Serious* (> 10 years).

Table 4-2 *Damage key for the probability distribution of theoretical recovery time by acute reduction of seabird- and marine mammal stocks with low recovery potential (V3) (OLF, 2007).*

Acute reduction of the stocks	**Consequence category – Environmental damage** **Theoretical recovery time in year**			
	Minor <1 year	**Moderate 1-3 years**	**Considerable 3-10 years**	**Serious >10 years**
1-5 %	50 %	50 %		
5-10 %	25 %	50 %	25 %	
10-20 %		25 %	50 %	25 %
20-30 %			50 %	50 %
≥ **30 %**				100 %

The calculations performed for the coastal habitat will differ from the VEC populations, by utilizing a combined effect- and damage key that links the amount of oil in a 10 × 10 km habitat directly to the environmental damage and recovery time.

Step 4 – Environmental risk is there after calculated by combining the likelihood of various environmental damages with the frequency of the specific oil leak and can then be measured against the operator’s acceptance criteria for environmental damage.

4.1 Uncertainty in environmental risk analyses

According to the Norwegian Petroleum Safety Authority’s (2015) updated definition of the risk concept, it states that uncertainty should be addressed as part of any risk assessment. The following section is included to highlight the most significant uncertainties related to input data, models and methods used in the environmental risk analysis.

The aim in an environmental risk analysis is to decrease the uncertainty as much as possible by using the best available knowledge at any given point in time. This means that some conservative choices must be made for parameters where knowledge is limited in order to ensure that the uncertainty is taken into account.

While reading an environmental risk analysis, one may perceive the environmental risk as a specific quantity that unconditionally can determine if a planned activity is acceptable or unacceptable with respect to the calculated effect on the environment. It is easy to forget that behind the risk result, a number of choices with smaller or larger degree of uncertainty have been made, e.g.:

The methodology includes a large degree of uncertainty, since it is not feasible to predict the exact (calculated) effect of a potential future oil spill. To take into account the uncertainty in effects for populations of seabirds and marine mammals given the influence of an oil spill, a set of “effect keys” is made. The effect keys give possible population losses given encounters of a range of different oil masses (e.g. 1-100 tonnes of oil per 10 × 10 km grid cell, giving 20 % population loss). Calculated population loss is categorized further within different ranges (e.g. 1-5 %, 5-10 % and so on), which gives a range of theoretic restitution time (e.g. 10-20 % population loss gives 25 % probability for *Moderate* environmental damage, 50 % probability for *Considerable* environmental damage and 25 % probability for *Serious* environmental damage, respectively).

The presence of the natural resources can be a highly uncertain and variable size. The collected and modelled data for seabirds in the nesting season is generally good. The datasets are based on statistical analysis of counting data and is frequently updated through the Seapop-program. However, it is not possible to predict the exact presence of seabirds due to large variations from year to year, especially for pelagic seabirds. The datasets presents an “average” value of the densities of seabirds and not the actual distribution at a given time. For seabirds connected to partially ice covered waters the uncertainties are even more profound, as the presence is determined by yet another variable, the presence, concentrations and orientation of the marginal ice zone.

For fish eggs/larvae in the water column, the analysis is based on modelled data for larvae distribution in the water column for different years. Several years of data and realistic distributions are necessary to produce results for possible larvae loss as accurate as possible, which fits the expectations. It is also possible to highlight the uncertainty/variations by presenting maximum and minimum loss values as well as standard deviation to obtain more complete results.

The choice of a reference oil type to represent a potential future hydrocarbon fluid performed with a varying degree of uncertainty. In a few cases there are good indications with respect to oil properties, which are important to select an analogue oil type, while in other cases little information exists. It can be difficult to find an existing oil type which represents the weathering properties of the expected oil. In addition there is uncertainty related to the oil behavior on the water surface/in the water column after releases during different times of the year, in different weather situations and the in weather conditions itself.

To take into account the uncertainty in the exterior environmental parameters (wind, current, temperature) it is important to model a sufficient number of simulations. This implies a sufficient number of simulations throughout the year in order to obtain seasonal variation (or monthly), and an adequate number of years to ensure annual variation. Today, data from 1998 to 2005 is utilized for sea current, however in the near future it should be possible to use at least the last ten years of data to ensure a better statistical basis.

The current version of OSCAR (v6.2) contributes to increased uncertainty when calculating oil masses on the sea surface. This occurs when the oil masses are exported from a 3 × 3 km grid (used in the model setup) to a 10 × 10 km grid (used in environmental risk modelling), where the oil masses are over estimated. This is a source of uncertainty/error which will be improved in the newest version of OSCAR (v7.01).

When calculating risk, both consequence estimates (what is the consequence if a blowout occurs) and probability estimates (how probable is it that this event will occur) are included. The probability estimates are based on incident numbers from historical data for the North Sea (Norwegian, British and German sector) and the outer continental shelf of the Mexico Gulf. It is linked a large uncertainty to how good these empirical data are to describe/predict future incidents. When calculating generic blowout frequencies, earlier the latest 20 years of incidents was utilized, but the methodology has been changed to ensure the latest year’s technology development in the petroleum industry is taken into account. Today data from 1.1.1980 to 31.12.2011 is utilized with a bigger weight on the latest incident (Lloyd's Register Consulting, 2015).

To reduce the uncertainty linked to the blowout probability it is possible to perform well specific risk analyses where several well specific parameters are evaluated against empirical data. In many cases the outcome is a reduced specific blowout frequency compared to the empirical value. This is due to the fact that oil operators on the Norwegian Continental Shelf in many cases have better control and routines than what is the basis for the historical events. By using the generic blowout frequencies, uncertainty is taken into account by making a conservative choice.

5 ENVIRONMENTAL RESOURCES

Environmental resources included in the ERA are briefly mentioned in this chapter and further described in Appendix C. For a more extensive description of the natural resources in the Barents Sea area, it is referred to the Management Plan for the Barents Sea (Meld. St. 8 (2005-2006) and Meld. St. 10 (2010-2011)), (Føyn, von Quilfeldt, & Olsen, 2002), (Loeng & Drinkwater, 2007), (N. P. Havforskningsinstituttet, Miljødirektoratet, Norsk institutt for naturforskning, 2010) and the impact assessment related to opening of petroleum research in the Barents Sea southeast (Olje- og enegidepartementet, 2012), (HI, 2012), (G.H. Systad & Strøm, 2012).

The potential damage to specific Valued Ecosystem Components (VECs) creates the basis for the assessment of the environmental risk level. These components are used as risk indicators in the environmental risk analysis.

5.1 Valued ecological components (VECs)

According to the Norwegian Oil and Gas Association (OLF, 2007) a VEC is defined as a resource or an environmental characteristic that:

- is important to local human populations, or
- has a national or international interest, and
- if changed from the present state, it will have importance for how the environmental impact is considered, and for which mitigating measures is chosen

The selection of VECs within an influence area is based on the following priority criteria:

- VEC must represent a population, a society or a habitat,
- VEC must be vulnerable to oil contamination in the relevant season,
- VEC population must be represented by a high proportion of the population within the influence area,
- VEC population must be present most of the year, or in the relevant season, and
- VEC habitat must have a high probability for being exposed to oil.

The selection also considers red list species and thus ensures that the ERA is carried out for the type of resources with a high probability of being affected by oil pollution. In such an analysis it is vital that the best available population data is used, and separate studies should be acquired when necessary.

Based on the criteria listed above several species of seabirds, marine mammals and fish are included in the ERA. In the following sections species included in the ERA in each of the VEC categories are listed.

5.1.1 Seabirds

Seabird species in the Barents Sea area is included in the analysis and both pelagic and coastal populations are considered. However, the pelagic species are most relevant due to the offshore location of the well, with limited potential for oil to shore.

The population datasets are divided in two; open sea seabirds and coastal seabirds; at Finnmark and seabirds connected to the archipelagos of Spitsbergen (Svalbard and Bjørnøya). The two datasets have a certain degree of overlap, where in particular pelagic seabirds are represented in the coastal seabird dataset during breeding/nesting season (spring and summer). Immature individuals remain offshore in pelagic waters and are thus covered by the dataset describing pelagic seabirds during the breeding/nesting period. The datasets are developed through the Seapop-program (Seapop, 2011, 2012, 2013).

NINA (the Norwegian institute for nature research) has, through the Seapop-program, collected data for Common Guillemot originating from three different colonies in the Barents Sea (Bjørnøya, Hjelmsøya and Hornøya) and one in the Norwegian Sea (Sklinna), for birds tracked with gls-loggers. The data differs from previous assumptions; indicating that the Barents Sea is also an important habitat throughout the year and not just limited to the breeding period. NINA has, based on the findings, developed new regional datasets for Common Guillemot for the autumn and winter (NINA v/Kjell E. Erikstad, 2015). The datasets are included in the present analysis.

In addition dynamic datasets prepared by DNV GL for Ivory gull is included in the analysis. These datasets gives the variable distribution of the species following the marginal ice zone (10-30 % ice concentration) for each month and year of data from the SVIM archive (ftp://ftp.met.no/projects/SVIM-public/SVIMresults/). The dataset are described in more detail in section 5.1.5.1.

A complete list of all seabird species considered in the environmental risk analysis, and the respective datasets, are given Table 5-1.

All datasets utilized in the analysis are illustrated in Appendix C.

Table 5-1 *Selected seabird VECs in the Barents Sea (Seapop, 2011, 2012, 2013). For Common Guillemot both Seapop-datasets and gls-logger data (NINA v/Kjell E. Erikstad, 2015) is used. Dynamic dataset connected to the ice zone developed by DNV GL (see Chapter 5.1.5). Red list information is from (Artsdatabanken, 2010).*

Species	Norwegian	Latin name	Redlist	Dataset
Ivory gull	Ismåke	*Pagophila eburnea*	VU	**Dynamic dataset (MIZ)**
Razorbill	Alke	*Alca torda*	VU	**Pelagic seabirds (open sea)**
Little Auk	Alkekonge	*Alle alle*	-	
European herring gull	Gråmåke	*Larus argentatus*	LC	
Fulmar	Havhest	*Fulmarus glacialis*	NT	
Northern gannet	Havsule	*Morus bassanus*	LC	
Kittiwake	Krykkje	*Rissa tridactyla*	EN	
Common guillemot* **	Lomvi	*Uria aalge*	CR	
Atlantic puffin	Lunde	*Fratercula arctica*	VU	
Thick-billed murre	Polarlomvi	*Uria lomvia*	VU	
Glaucous gull	Polarmåke	*Larus hyperboreus*	-	
Great black-backed gull	Svartbak	*Larus marinus*	LC	
Razorbill*	Alke	*Alca torda*	VU	**Coastal seabirds (including breeding populations)**
Little Auk**	Alkekonge	*Alle alle*		
Common gull	Fiskemåke	*Larus canus*	NT	
European herring gull**	Gråmåke	*Larus argentatus*	LC	
Red-necked grebe	Gråstrupedykker	*Podiceps grisegena*	LC	
Long-tailed duck	Havelle	*Clangula hyemalis*	LC	
Fulmar*	Havhest	*Fulmarus glacialis*	NT	
Northern gannet	Havsule	*Morus bassanus*	LC	
Great northern loon*	Islom	*Gavia immer*	LC	
Kittiwake*	Krykkje	*Rissa tridactyla*	EN	
Common merganser	Laksand	*Mergus merganser*	LC	
Common guillemot*	Lomvi	*Uria aalge*	CR	
Atlantic puffin*	Lunde	*Fratercula arctica*	VU	
Thick-billed murre*	Polarlomvi	*Uria lomvia*	VU	
Glaucous gull*	Polarmåke	*Larus hyperboreus*	-	
King eider*	Praktærfugl	*Somateria*	-	
Red-breasted merganser	Siland	*Mergus serrator*	LC	
Velvet scoter	Sjøorre	*Melanitta fusca*	NT	
Red-throated loon	Smålom	*Gavia stellata*	LC	
Steller's eider*	Stellerand	*Polysticta stelleri*	VU	
Great cormorant	Storskarv	*Phalacrocorax carbo*	LC	
Common scoter	Svartand	*Melanitta nigra*	LC	
Great black-backed gull	Svartbak	*Larus marinus*	LC	
Black guillemot*	Teist	*Cepphus grylle*	VU	
European shag	Toppskarv	*Phalacrocorax*	LC	
Common eider*	Ærfugl	*Somateria molissima*	LC	

VU – vulnerable, NT – near threatened, LC – least concern, EN – endangered, CR – critically endangered

*Coast of Finnmark and Svalbard/Bjørnøya (two different datasets)

**Only at Svalbard/Bjørnøya

*** For Common Guillemot the opens sea datasets includes both “standard” Seapop-datasets and gls-logger data.

5.1.2 Marine mammals

For marine mammals the species listed in Table 5-2 are identified as potentially affected given an oil spill from the “BaSEC well”, since the oil drift modelling results indicate a (small) potential for oil pollution in coastal waters as well as in the marginal ice zone in case of a blowout. The species connected to the coastal areas will be subjected to a quantitative analysis, as applicable datasets are available for this area. Grey seal and Harbour seal are most vulnerable during their birth- and moulting periods when they gather in colonies in coastal areas. The Grey seal forms colonies in September-December (birth), with delayed mating with increasing latitude, and in February-March (moulting). The Harbour seal forms colonies in June-July (birth) and in August-September (moulting). The common otter is considered equally vulnerable all year. In addition marine mammals in the marginal ice zone are evaluated. The main species relevant for the marginal ice zone is Ringed seal, Bearded seal and Harp seal, as well as Polar bear.

Table 5-2 *Selected marine mammal applied in the environmental risk analysis for the BaSEC project. Red list information is from Artsdatabanken (2010).*

Name (English)	Name (Norwegian)	Name (Latin)	Red list	Dataset
Grey seal	Havert	*Halichoerus grypus*	LC	**Barents Sea – coastal areas**
Harbour seal	Steinkobbe	*Phoca vitulina*	VU	
Common otter	Oter	*Lutra lutra*	VU	
Ringed seal	Ringsel	*Phoca hispida*	LC	**Barents Sea – marginal ice zone**
Bearded seal	Storkobbe	*Erignathus barbatus*	LC	
Harp seal	Grønlandssel	*Pagophilus groenlandicus*	LC	
Polar bear	Isbjørn	*Ursus maritimus*	VU	

LC – Least concern; VU – Vulnerable; EN – Endangered

5.1.3 Coastal habitats

There is a small potential that an oil spill from the BaSEC well location will reach land at Hopen, Bjørnøya, Novaya Zemlya or the Norwegian coastline. Based on this the coastal habitats are included in the damaged based environmental risk analysis.

5.1.4 Fish

The effect of oil on organisms in the water column (fish and plankton) depends on the oil type, degree of natural dispersion and kinetics of the release of oil components to the water column, and the duration of exposure. Since plankton (phyto-and zooplankton) are generally less vulnerable to oil pollution, the main focus of the environmental risk analysis is for fish. Eggs and larvae can be very vulnerable to oil pollution in the water, while juveniles (greater than about 2 cm) and adult fish are not thought to be affected as much. This is consistent with field observations that have shown little mortality of adult fish for real oil spill incidents.

Fish species spawning in a limited area over a narrow time period have the highest potential for being affected by an acute oil spill. Of the most important commercial species in the Barents Sea, only Cod and Capelin spawn in a limited geographical area. These two species are therefore evaluated in the analysis.

5.1.5 The marginal ice zone

The ecosystem connected to the marginal ice zone (MIZ) is vital for all marine life in the Barents Sea, and an acute oil spill in the area may cause serious damage. It is in particular the large concentrations of seabirds that make the ecosystem vulnerable for acute pollution, but a potential oil spill may also harm plankton, fish species such as capelin and polar cod, as well as marine mammals using the sea ice as a haul-out place and for reproduction. The biological activity follows the ice edge northward during spring and summer. According to the updated Management plan for the Barents Sea the *marginal ice zone* is defined as the area of ≥ 15 % ice concentration in more than 30 % of the time (Klima - og Miljødepartementet, 2015). Based on the oil trajectory modelling results and statistical ice coverage data the potential for surface oil entering the ice covered waters is limited (see section 3.3.7), and mainly relevant in the late winter/early spring period. For assessing further potential effects of oil in the marginal ice zone a quantitative analysis for the Ivory gull will be carried out. The dataset is described below in section 5.1.5.1.

Maps showing the average ice cover in the period from 2001-2011 based on data from met.no (MI, 2012) is given in Appendix C.

5.1.5.1 The dynamic VEC-dataset – Ivory Gull

Due to the large variation in climate (like temperature, ice coverage etc.) and prey availability, the presence of natural resources are highly variable. The uncertainty is especially important in Arctic areas and the variability in ice coverage should be taken into account when preparing datasets for distribution of ice associated species. The presence of ice affects both oil drift and species vulnerability towards oil pollution. DNV GL and Akvaplan-niva have cooperated in the development of a methodology with the purpose of addressing environmental risk in the marginal ice zone (Norsk olje og gass, 2014). The project identified a lack of detailed biological resource data for the Northern Barents Sea and a need for preparing dynamic, ice dependent, VEC-datasets. The project is further described in the *Method description - environmental risk* in Appendix A.

Ivory gull is identified as the representative VEC species for risk analysis in the marginal ice zone. It is chosen for the purpose of being associated with ice zone all year round, as well as being one of few sympagic birds in the northern hemisphere, a poorly known species and probably one of the most threatened bird species due to bio magnification of contaminants. The species if further described in the *resources description* in Appendix C.

DNV GL has prepared ice and dynamic VEC- files in ArcGIS. It is assumed that the Ivory Gulls are evenly distributed in a restricted area east-western bound by Svalbard and in the north by Franz Josef Land in waters with 20-50 % ice concentrations. Based on this assumption, one VEC-file per oil drift simulation potentially encountering the zone of 20-50 % ice concentration is made. This boundary differs slightly from the definition of the marginal ice zone, which is ≥ 15 % ice concentration, but is still part of the "marginal ice zone". In the analysis the oil drift simulations and the corresponding ice concentration files are matched in time, giving the accurate effects associated with each simulation.

5.1.6 The polar front

The polar front is defined as an area of particularly environmental sensitivity ("SVO – Særlig verdifullt område") according to the Management Plan for the Barents Sea (Meld. St. nr. 10 (2010-2011)), due to high biological production and diversity. The polar front is formed in the transition zone where the warmer Atlantic water meets the cold polar water, forming an oceanographic front (Klima - og Miljødepartementet, 2015). During winter the polar front coincide, to a large extent, with the ice edge.

The resource was selected with the aim of model potential effects on species concentrated along the polar front area. This was based on a conservative assumption that the total population is distributed evenly along the eastern part of the polar front; the area potentially affected given an oil blowout from the BaSEC well. It is assumed that the species is of high vulnerability (vulnerability index 3 according to the ERA-methodology). The polar front and the selected grid cells in the western part of the polar front are illustrated in Figure 5-1.

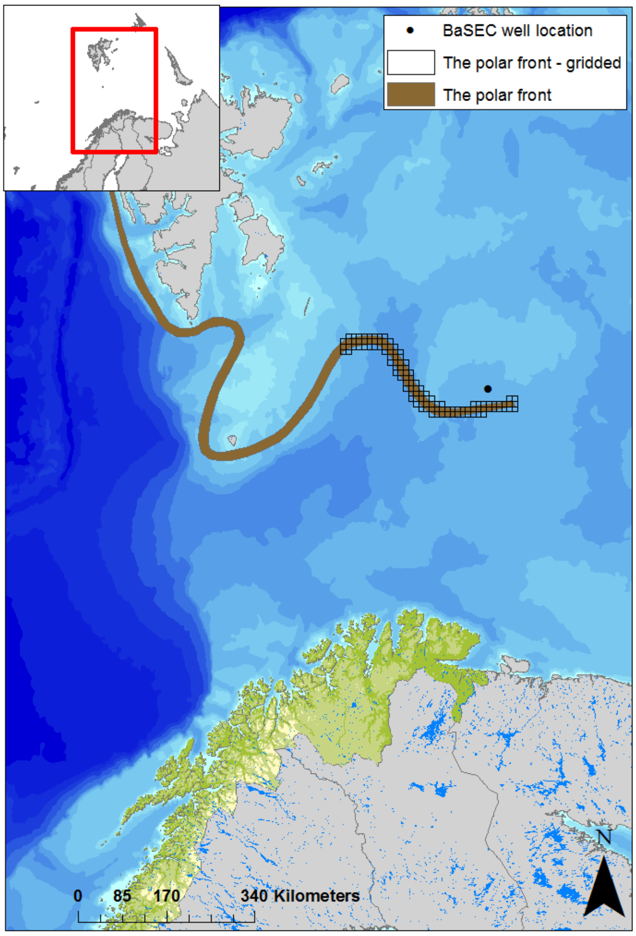


Figure 5-1 *The polar front, defined as a "particularly valuable and vulnerable area" (SVO).*

6 ENVIRONMENTAL RISK ANALYSIS RESULTS

In this section the quantified consequences and risk for seabirds, marine mammals, coastal habitats and fish are presented for the selected scenario (see Chapter 2) for the BaSEC well location, based on all rates and durations, and their individual probabilities (unless denoted otherwise).

Possible consequences for seabirds and marine mammals are estimated as the probability for a given loss of the population (respectively <1 %, 1-5 %, 5-10 %, 10-20 %, 20-30 % and > 30 %), and the corresponding environmental *damage*, defined by restitution time.

The calculations are based on monthly population distributions of the species presented in Section 5.1, and the results are presented seasonally. The maximum population loss/environmental damage within each season (spring: March-May, summer: June-August, autumn: September-November and winter: December-February) denotes the seasonal results. For the consequence calculations the worst affected VEC is presented within in each season, whereas risk is presented for all affected species.

Possible consequences for coastal habitats are estimated as the probability for stranding of a given mass of oil (respectively 1-100 tonnes, 100-500 tonnes, 500-1000 tonnes or > 1000 tonnes) per 10 × 10 km grid cell. The potential environmental damage is calculated directly from the mass of oil entering each habitat, defined as a 10 × 10 km area. The seasonal results are presented for the worst affected habitat, whereas the risk is presented for the ten worst affected habitats in each season, as for the VEC-species.

Environmental damage is defined in terms of potential restitution time where:

- 1 month -1 year is defined as **Minor** environmental damage,
- 1-3 years is defined as **Moderate** environmental damage,
- 3-10 years is defined as a **Considerable** environmental damage, and
- 10 years is defined as **Serious** environmental damage.

The restitution time is defined as the time it takes before the population is back at 99 % of undisturbed level. In the MIRA-method, restitution time for population losses < 1 % is therefore not calculated (OLF, 2007a), and the results are therefore only presented for species with probability for more than 1 % population loss.

6.1 Population loss and environmental damage

The probability for population losses and the probability for environmental damage/restitution time are presented in the following chapter for the Barents Sea-populations. Results for pelagic seabirds, coastal seabirds, marine mammals and coastal habitats are presented.

6.1.1 Pelagic seabirds

The calculated probability for population loss and environmental damage given a topside blowout are presented in Figure 6-1. *Black-legged Kittiwake* has the highest probability for population loss independently of the season.

Highest probability for population loss is calculated to, all referring to *Black-legged Kittiwake*:

- 29 % probability for loss of 1-5 % of the population (autumn).
- 4 % probability for loss of 5-10 % of the population (spring).

There is no probability for >10 % population loss.

The corresponding probabilities for environmental *damage* with respect to restitution time for Black-legged Kittiwake are:

- 15 % probability for *Minor* environmental damage (autumn).
- 15 % probability for *Moderate* environmental damage (autumn).
- 1 % probability for *Considerable* environmental damage (spring).

There is no probability for damage with respect to recovery time in the category *Serious* environmental damage.

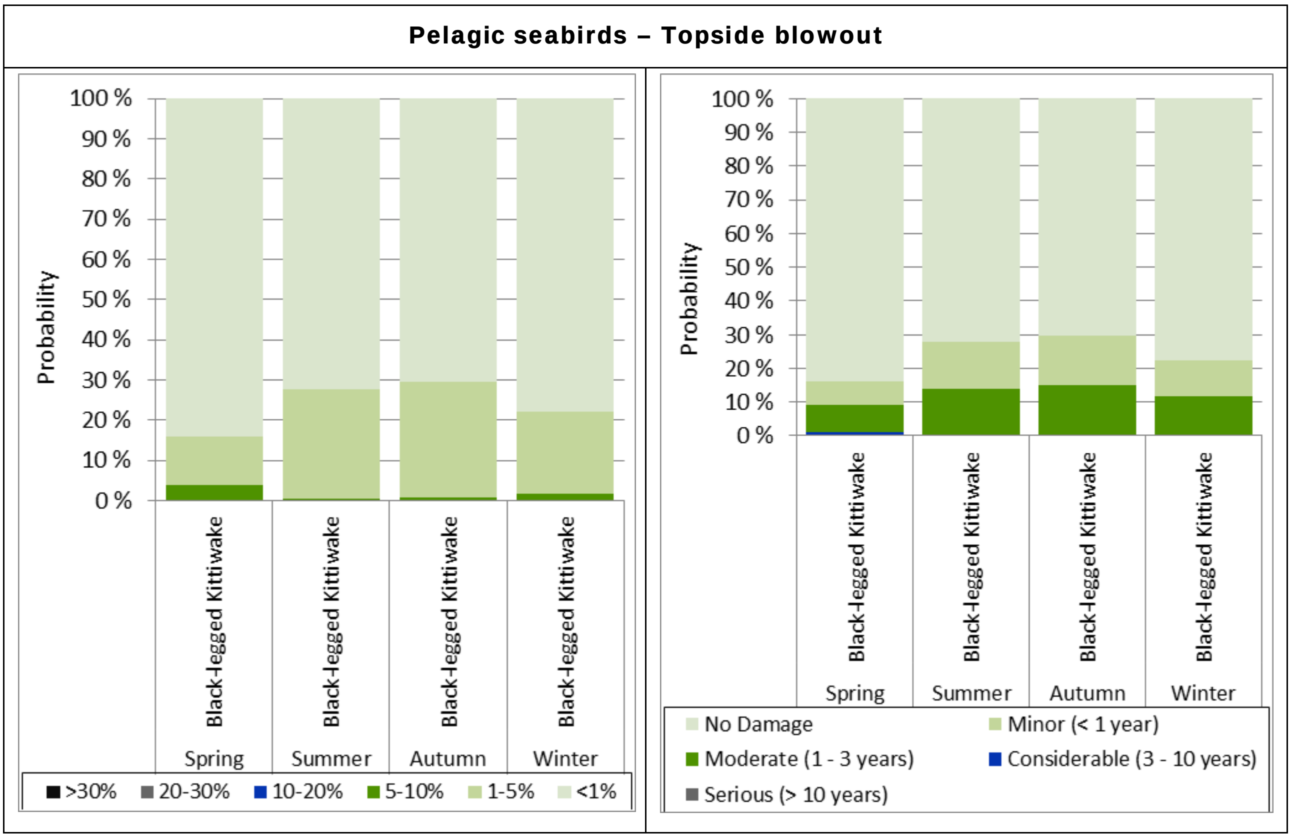

Pelagic seabirds – Topside blowout

Figure 6-1 *Probability distribution for population losses (left) and probability distribution for damage/recovery time (right) for the worst affected populations of pelagic seabirds in case of a topside blowout from the BaSEC well, presented seasonally. Population loss is grouped in six categories; <1 %, 1-5 %, 5-10 %, 10-20 %, 20-30 % and >30 % and environmental damage/recovery time is defined as follows: No damage, Minor, Moderate, Considerable and Serious.*

The calculated probability for population loss and environmental damage given a subsea blowout are presented in Figure 6-2. *Black-legged Kittiwake* has the highest probability for population loss independent of season.

Highest probability for population loss is calculated to, all referring to *Black-legged Kittiwake*:

- 30 % probability for loss of 1-5 % of the population (autumn).
- <0.5 % probability for loss of 5-10 % of the population (winter).

There is no probability for >10 % population loss.

The corresponding probabilities for environmental *damage* with respect to restitution time for Black-legged Kittiwake are:

- 15 % probability for *Minor* environmental damage (autumn).
- 15 % probability for *Moderate* environmental damage (autumn).
- <0.5 % probability for *Considerable* environmental damage (winter).

There is no probability for damage with respect to recovery time in the category *Serious* environmental damage.

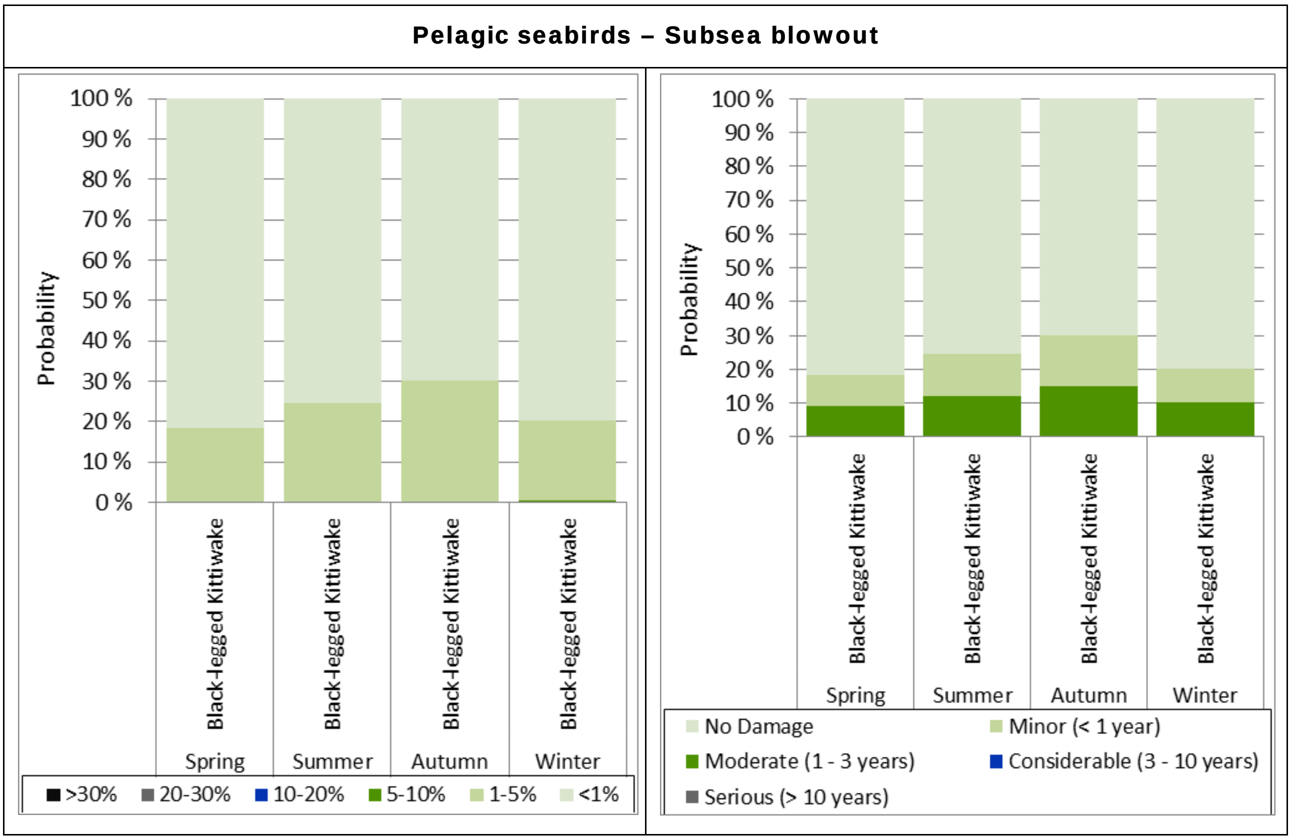


Figure 6-2 *Probability distribution for population losses (left) and probability distribution for damage/recovery time (right) for the worst affected populations of pelagic seabirds in case of a subsea blowout from the BaSEC well, presented seasonally. Population loss is grouped in six categories; <1 %, 1-5 %, 5-10 %, 10-20 %, 20-30 % and >30 % and environmental damage/recovery time is defined as follows: No damage, Minor, Moderate, Considerable and Serious.*

6.1.2 Common Guillemot – gls-loggers

The calculated probability for population loss and environmental damage given a topside blowout and subsea blowout are presented in Figure 6-1. The “population” from the colony at *Sklinna* has the highest probability for population loss in the autumn season, and the “population” from *Hjelmsøya* has the highest (but lower compared to Sklinna in the autumn) probability for population losses in the winter season.

Highest probability for population loss is calculated to, all referring to *the* colony from Sklinna, given a topside blowout:

- 24 % probability for loss of 1-5 % of the population.
- 6 % probability for loss of 5-10 % of the population.
- <1 % probability for loss of 10-20 % of the population.

There is no probability for >20 % population loss.

The corresponding probabilities for environmental *damage* with respect to restitution time for Common guillemot are:

- 13 % probability for *Minor* environmental damage.
- 13 % probability for *Moderate* environmental damage.
- 1 % probability for *Considerable* environmental damage.
- <0.5 % probability for *Serious* environmental damage.

The potential losses and environmental *damage* associated with a subsea blowout are slightly lower;

- 20 % probability for loss of 1-5 % of the population.
- <1 % probability for loss of 5-10 % of the population.

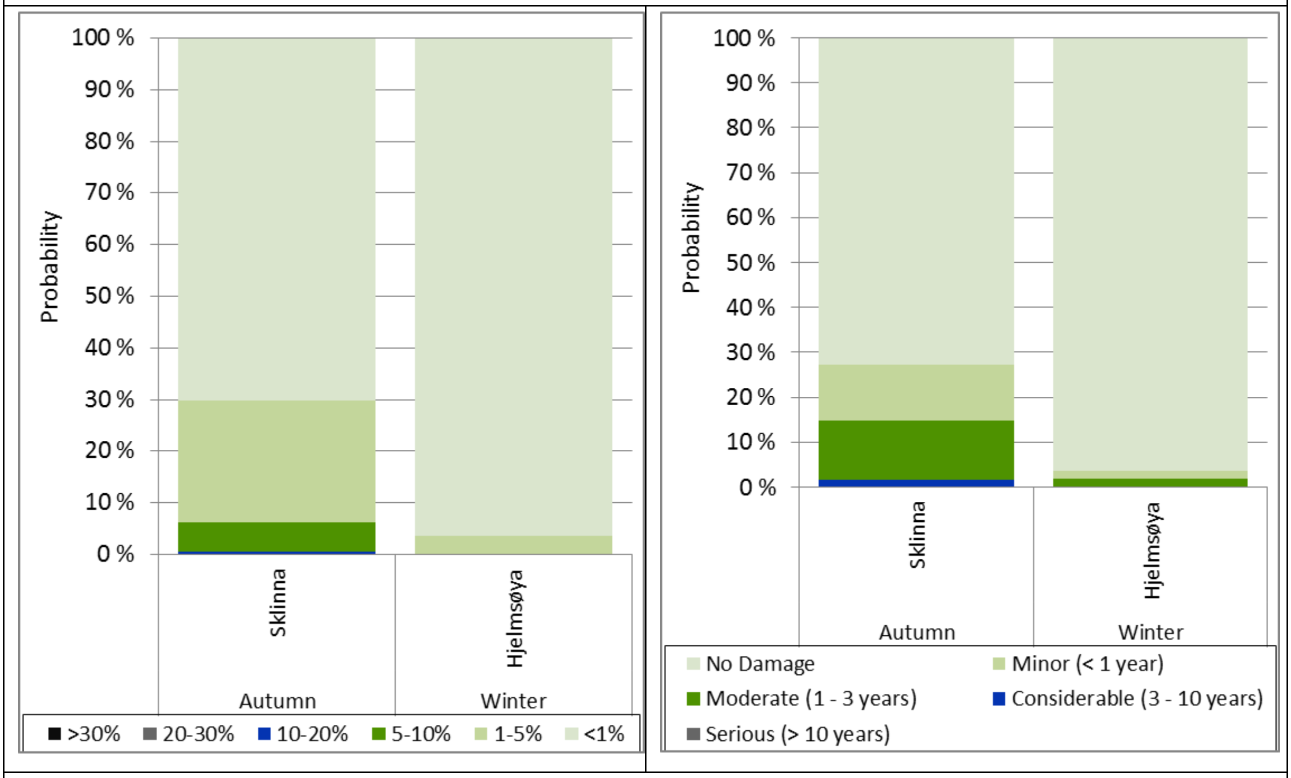
There is no probability for >10 % population loss given a subsea blowout from the well.

The corresponding probabilities for environmental *damage* with respect to restitution time for Common guillemot are:

- 10 % probability for *Minor* environmental damage (autumn).
- 10 % probability for *Moderate* environmental damage (autumn).
- <0.5 % probability for *Considerable* environmental damage (winter).

There is no probability for damage with respect to recovery time in the category *Serious* environmental damage given a subsea blowout.

Common guillemot – Topside blowout



Common guillemot – Subsea blowout

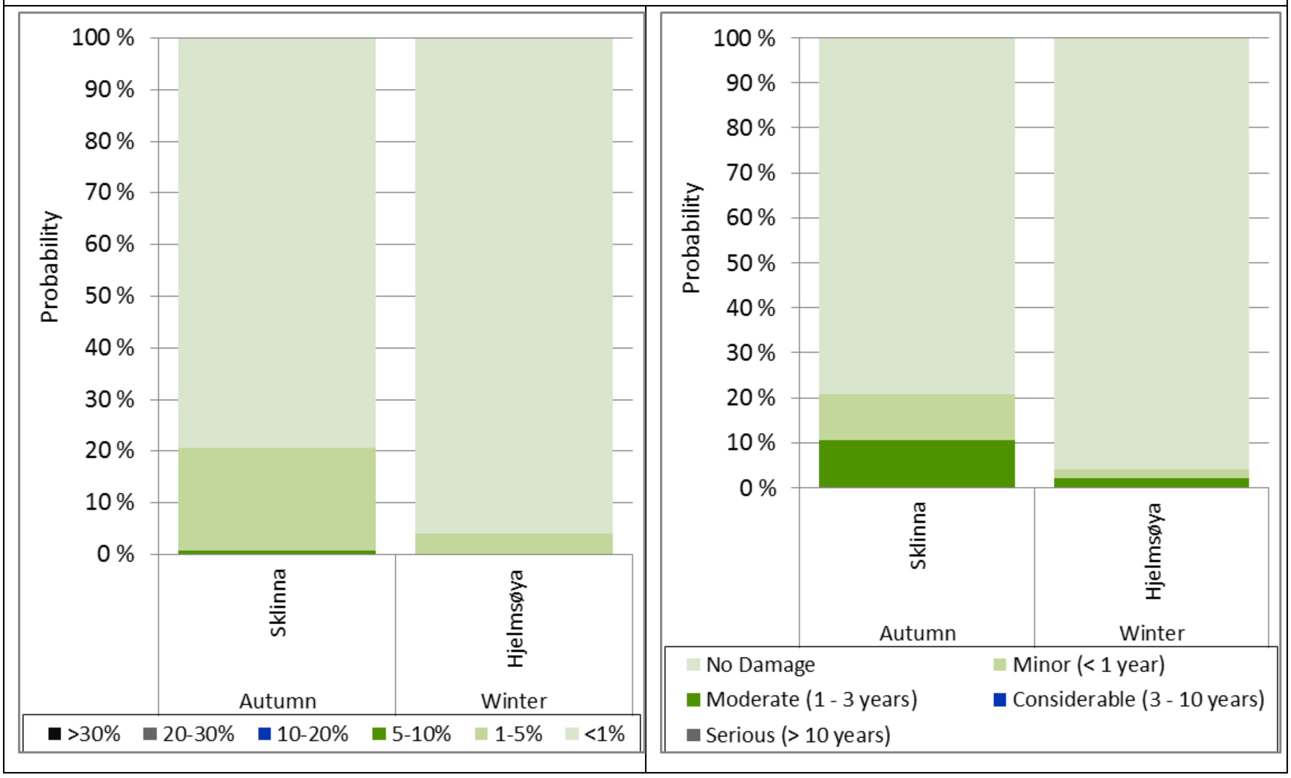


Figure 6-3 *Probability distribution for population losses (left) and probability distribution for damage/recovery time (right) for the potentially most affected colonies of Common guillemot in case of a topside (upper figures) or subsea (lower figures) blowout from the BaSEC well, presented for the autumn and winter season. Population loss is grouped in six categories; <1 %, 1-5 %, 5-10 %, 10-20 %, 20-30 %*

and >30 % and environmental damage/recovery time is defined as follows: No damage, Minor, Moderate, Considerable and Serious.

6.1.3 Ivory Gull – dynamic dataset in the marginal ice zone

The possible population losses of Ivory Gull in the marginal ice zone are calculated for all topside simulations with start date in February- April for the period of 1999 to 2004 and with duration of 14 days. The total number of simulations is 33, whereas the total number of simulations encountering the ice zone varies between 6 and 7 for each blowout rate. The results are given as average population loss for the simulations potentially affecting the ivory gull, and maximum population loss in Table 6-1 and further illustrated in Figure 6-4. For rates 1, 2, 3 and 5 only one simulation (3 %) gives population losses exceeding 1 %, whereas two simulations (6 %) gives population losses exceeding 1 % for rate 4. < 1 % population loss is defined as *no effect* according to the ERA methodology. The average, as well as the maximum population loss increase with increasing rate, from 1.1 % for rate no. 1 to 1.8 % for rate no. 5 (*average*) and from 5.4 % for rate no. 1 to 9.1 % for rate no. 5 (*maximum*). However, taking into account all oil drift simulations in the same period, the probability for <1 % population loss, corresponding to *no damage* (< 1 month restitution time), is 94-97 %.

The calculated population losses correspond to 2 % probability for *Minor* damage, 3 % probability for *Moderate* damage and 1 % probability for *Considerable* damage according to the ERA methodology, see Table 6-2. There is no calculated probability for *Serious* environmental damage (> 10 years restitution time).

Table 6-1 *Results of population loss calculations for Ivory gull in 20-50 % ice concentrations at the sea surface based on all oil drift simulations potentially affecting the defined ice zone. The results are given as number of simulations with hits, average loss for the simulations with hits and overall maximum loss.*

Rate	No. of simulations with hit	Average loss	Max loss	Probability for population loss		
				<1 %	1-5 %	5-10 %
1	7	1.1 %	5.4 %	97 %	-	3 %
2	6	1.2 %	5.9 %	97 %	-	3 %
3	6	1.3 %	6.9 %	97 %	-	3 %
4	7	1.6 %	8.3 %	94 %	3 %	3 %
5	6	1.8 %	9.1 %	97 %	-	3 %

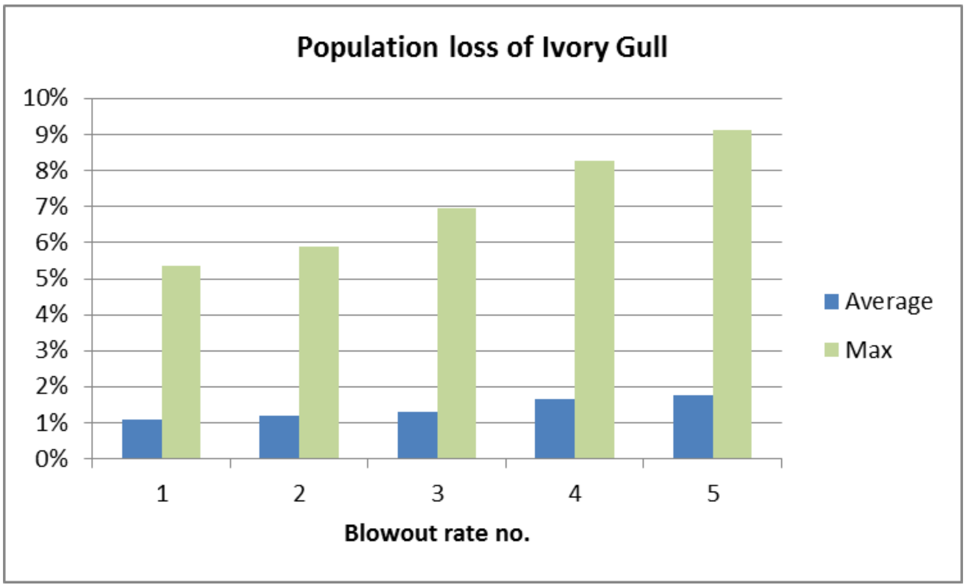


Figure 6-4 *Illustration of average and maximum population loss of Ivory gull.*

Table 6-2 *Probability distribution for environmental damage/recovery time for Ivory Gull in the period February-April.*

Minor <1 year	Moderate 1-3 years	Considerable 3-10 years	Serious >10 years
2.3 %	3.0 %	0.8 %	-

6.1.4 Coastal seabirds

There is no probability for population losses of seabirds in coastal areas (Finnmark or Svalbard/Bjørnøya) exceeding 1 % of the total populations given a blowout from the BaSEC well, based on all rates and durations. Potential effects of an oil spill are therefore considered negligible for seabirds in coastal areas and not taken further in calculations of environmental risk.

6.1.5 Marine mammals in the ice zone

If assuming that marine mammals (seals) connected to the ice are limited to a somewhat restricted area of the ice zone, with ice concentrations 20-50 %, the dynamic dataset modelling performed for Ivory gull could very well be valid for mammals (seals) as well. However, the mammals are assumed less vulnerable to oil pollution than sea birds and thereby slightly smaller population losses associated with oil exposure which are reflected in the effect keys given in the ERA methodology. Combining the results for Ivory gull and the effect keys for marine mammals the effects are considered small or negligible. It should however be noted that simulations affecting the Ivory gull in the ice zone may very well also affect other resources dependent of the ice zone and damage to marine mammals is possible given the right wind and current conditions, as well as a particularly southern orientation of the ice zone.

Other marine mammals such as whales are assumed less restricted to the ice edge areas and less vulnerable to oil pollution. The polar bears are present in the same areas as the seals, however in smaller numbers. The Barents Sea population of polar bears is distributed over a larger area, and as they hunt and wander in solitary the effects are expected on an individual level. The presence, effects and vulnerability to oil pollution is described in more details Appendix C.

6.1.6 Marine mammals in coastal areas

There is no probability for population losses of marine mammals in coastal areas (harbour seal, grey seal and otter) exceeding 1 % of the total populations given a blowout from the BaSEC well, based on all rates and durations. Potential effects of an oil spill are therefore considered negligible for marine mammals in coastal areas and not taken further in calculations of environmental risk.

6.1.7 Coastal habitats

There is no probability for pollution of more than 1 tonne oil per 10 × 10 km coastal habitat given a blowout from the BaSEC well, based on all rates and durations. Potential effects of an oil spill are therefore considered negligible for coastal habitats and not taken further in calculations of environmental risk.

6.1.8 Fish

Potential effects on fish eggs/larvae of cod and capelin were assessed quantitatively for a 14 day blowout duration combined with a rate of 5000 Sm^3/d (topside) and 4000 Sm^3/d (subsea).

The analysis showed no probability for losses exceeding 0.5 % of fish eggs and larvae in the water column, and it is therefore concluded that the risk for affecting substantial parts of the year class recruitment to the Norwegian population of these species is negligible.

Another species of special interest in the Barents Sea is Polar cod, as it plays an important role in the ecosystem; feeding on zooplankton and as a food source for other fish, whales, seals and birds. The Barents Sea stock seems to spawn in two separate areas; east of Spitsbergen and in the south-eastern regions of Barents Sea (http://www.imr.no), see Figure 6-5. As the figure indicates, the spawning areas are at a distance from the BaSEC well location, however larvae from the south-eastern population may drift into the area (but more likely in a more eastern oriented path). Due to the low water column concentrations following a spill from the BaSEC well the expected effects are small/negligible.

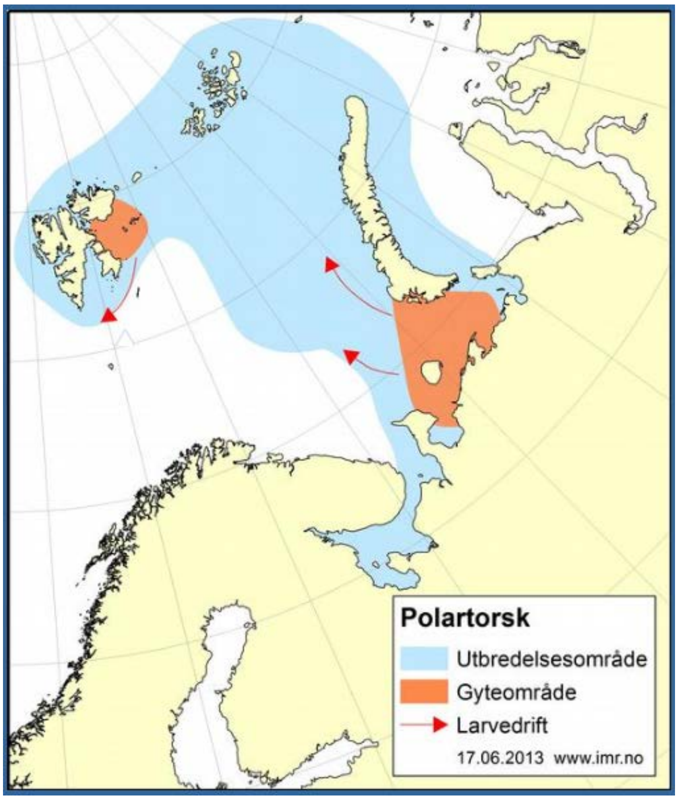


Figure 6-5 *Map of distribution of Polar Cod; orange illustrating the spawning areas, red arrows illustrating the larvae drift and blue area illustrating the general distribution (Havforskningsinstituttet, 2014).*

6.1.9 Populations concentrated in the polar front area

As a conservative approach to addressing the potential effects of an oil blowout from the BaSEC well on populations concentrated in the polar front area, it is assumed that a (seabird) population is evenly distributed in grid cells along the eastern part of the polar front (see Section 5.1.6). The seabird population is assumed vulnerable with *vulnerability index* 3 according to the methodology (see Chapter 4).

Results are shown in Figure 6-6 for topside blowout and Figure 6-7 for subsea blowout.

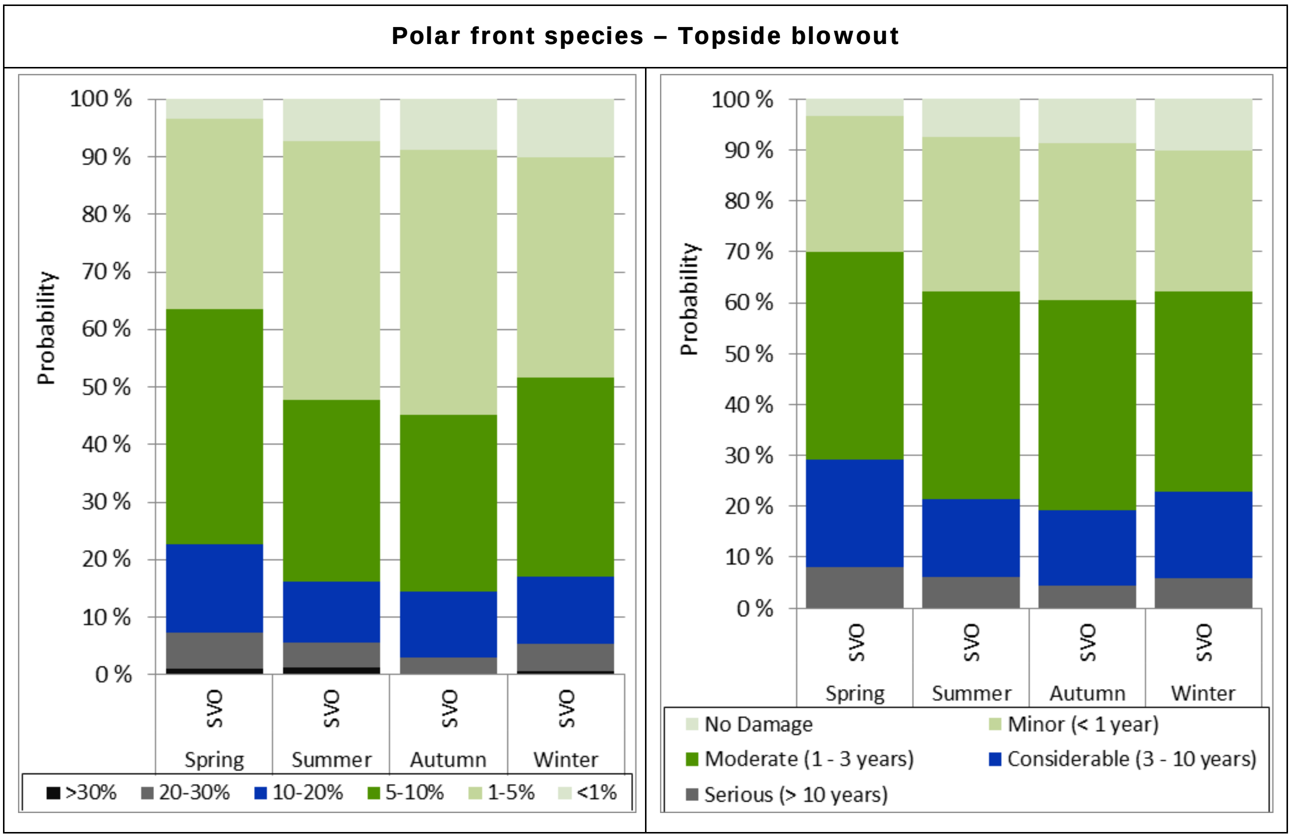
Highest probability for population loss given a topside blowout is calculated to:

- 46 % probability for loss of 1-5 % of the population (autumn).
- 41 % probability for loss of 5-10 % of the population (spring).
- 15 % probability for loss of 10-20 % of the population (spring).
- 6 % probability for loss of 20-30 % of the population (spring).
- 1 % probability for loss of >30 % of the population (summer).

The corresponding probabilities for environmental *damage* with respect to restitution time are:

- 31 % probability for *Minor* environmental damage (autumn).
- 41 % probability for *Moderate* environmental damage (autumn).
- 21 % probability for *Considerable* environmental damage (spring).

- 8 % probability for *Serious* environmental damage (spring)



Polar front species – Topside blowout

Figure 6-6 *Probability distribution for population losses (left) and probability distribution for damage/recovery time (right) for the worst affected populations of pelagic seabirds in case of a topside blowout from the BaSEC well, presented seasonally. Population loss is grouped in six categories; <1 %, 1-5 %, 5-10 %, 10-20 %, 20-30 % and >30 % and environmental damage/recovery time is defined as follows: No damage, Minor, Moderate, Considerable and Serious.*

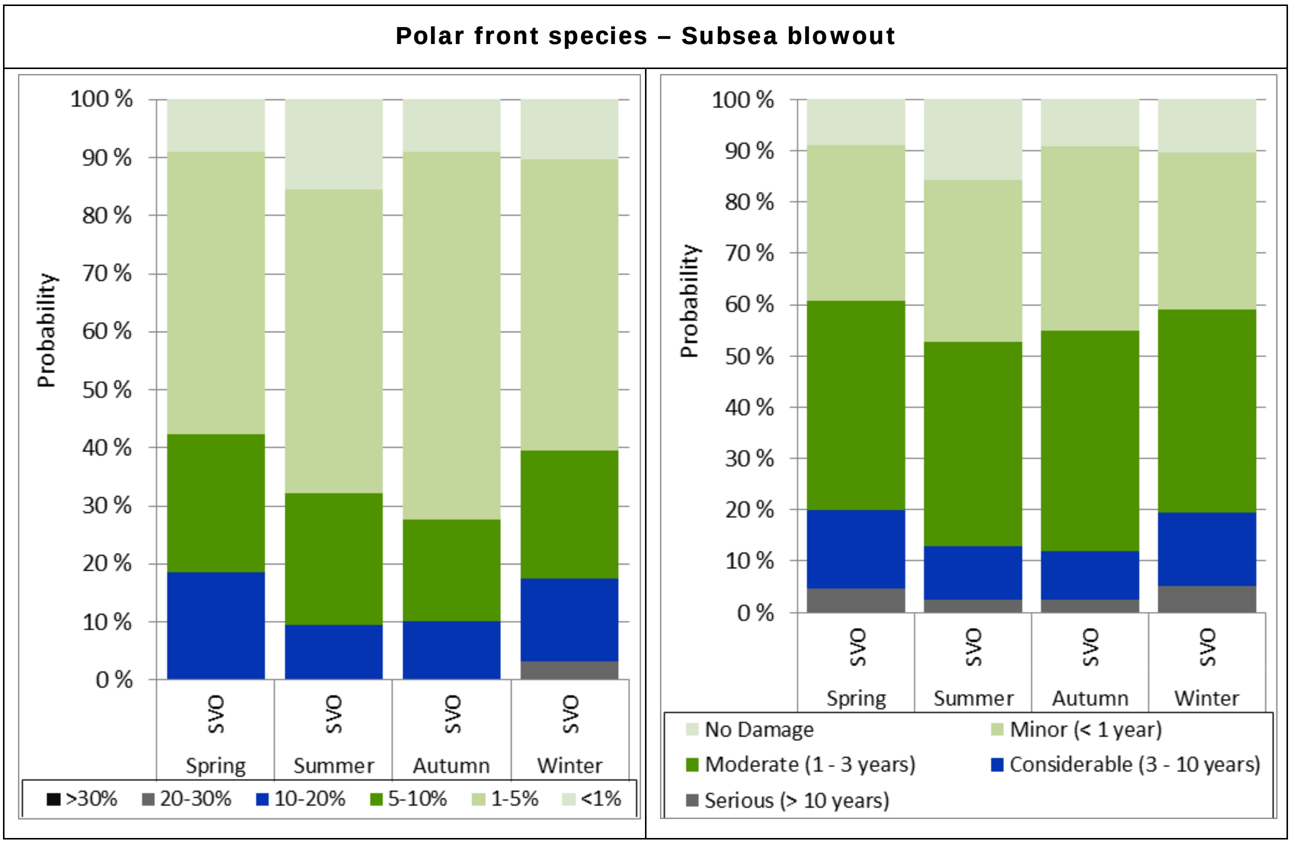
Highest probability for population loss given a subsea blowout is calculated to:

- 63 % probability for loss of 1-5 % of the population (autumn).
- 24 % probability for loss of 5-10 % of the population (spring).
- 18 % probability for loss of 10-20 % of the population (spring).
- 3 % probability for loss of 20-30 % of the population (winter).

There is no probability for >30 % population loss.

The corresponding probabilities for environmental *damage* with respect to restitution time are:

- 36 % probability for *Minor* environmental damage (autumn).
- 43 % probability for *Moderate* environmental damage (autumn).
- 15 % probability for *Considerable* environmental damage (spring).
- 5 % probability for *Serious* environmental damage (winter).



Polar front species – Subsea blowout

Figure 6-7 *Probability distribution for population losses (left) and probability distribution for damage/recovery time (right) for the worst affected populations of pelagic seabirds in case of a subsea blowout from the BaSEC well, presented seasonally. Population loss is grouped in six categories; <1 %, 1-5 %, 5-10 %, 10-20 %, 20-30 % and >30 % and environmental damage/recovery time is defined as follows: No damage, Minor, Moderate, Considerable and Serious.*

6.2 Environmental risk

Environmental risk calculations are performed in accordance with the ERA methodology. The risk is calculated for each seabird species based on the calculated conditional environmental damage, the generic blowout frequency (for oil well) and the “normal” acceptance criteria for operations at the Norwegian Continental Shelf, as given in Table 6-3.

Table 6-3 *The operation specific acceptance criteria for acute pollution used for assessing risk level in most environmental risk analysis on the Norwegian Continental Shelf (NCS).*

Severity of environmental damage	Duration of damage (Recovery / restitution time)	Operation specific acceptance criteria (per operation)
Minor	< 1 year	$< 1.0 \times 10^{-3}$
Moderate	1-3 years	$< 2.5 \times 10^{-4}$
Considerable	3-10 years	$< 1.0 \times 10^{-4}$
Serious	> 10 years	$< 2.5 \times 10^{-5}$

6.2.1 Seabirds at the open sea

The results for seabirds at the open sea are given in Table 6-4. Calculated risk is highest for the Barents Sea population of Black-legged Kittiwake in the autumn season, with 8 % of the acceptance criteria for *Moderate* environmental damage (1-3 year restitution time). The risk for restitution times exceeding 3 years is low (< 0.5 % of the acceptance criteria for *Considerable* damage), and there is no risk for *Serious* environmental damage (> 10 years restitution time).

Table 6-4 *Seasonal environmental risk calculation for pelagic seabird species applying the set of acceptance criteria defined in Table 6-3. Min/Mod/Conc/Ser refers to the damage categories defined according to restitution time.*

	Part of the Risk Acceptance Criteria															
Species	**Spring**				**Summer**				**Autumn**				**Winter**			
	Min	*Mod*	*Conc*	*Ser*	*Min*	*Mod*	*Conc*	*Ser*	*Min*	*Mod*	*Conc*	*Ser*	*Min*	*Mod*	*Conc*	*Ser*
Little Auk	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.1 %	0.0 %	0.0 %	0.1 %	0.3 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Northern Fulmar	0.4 %	1.6 %	0.0 %	0.0 %	1.1 %	4.6 %	0.0 %	0.0 %	1.2 %	4.8 %	0.0 %	0.0 %	0.3 %	1.4 %	0.0 %	0.0 %
Northern Gannet	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Black-legged Kittiwake	1.2 %	5.0 %	0.3 %	0.0 %	1.8 %	7.1 %	0.1 %	0.0 %	2.1 %	8.2 %	0.2 %	0.0 %	1.4 %	5.9 %	0.3 %	0.0 %
Atlantic Puffin	0.0 %	0.0 %	0.0 %	0.0 %	1.4 %	5.7 %	0.1 %	0.0 %	1.5 %	6.1 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Brünnich's Guillemot	0.8 %	3.2 %	0.0 %	0.0 %	1.4 %	5.5 %	0.0 %	0.0 %	1.3 %	5.4 %	0.0 %	0.0 %	0.7 %	2.7 %	0.0 %	0.0 %
Glaucous Gull	0.2 %	0.7 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.1 %	0.0 %	0.0 %	0.2 %	0.6 %	0.0 %	0.0 %
Maximum	***1.2 %***	***5.0 %***	***0.3 %***	***0.0 %***	***1.8 %***	***7.1 %***	***0.1 %***	***0.0 %***	***2.1 %***	***8.2 %***	***0.2 %***	***0.0 %***	***1.4 %***	***5.9 %***	***0.3 %***	***0.0 %***

🟩	10% - 20%
🟨	20% - 50%
🟧	50% - 100%
🟥	> 100%

6.2.2 Common guillemot – gls-loggers

The results for pelagic Common guillemot populations during autumn and winter are given in Table 6-5, based on gls-logger data for birds from the following colonies; Bjørnøya, Hornøya, Hjelmsøya and Sklinna. In addition, an analysis has been carried out for all the colonies combined. Calculated risk is highest for the Sklinna population in the autumn season, with 6 % of the acceptance criteria for *Moderate* environmental damage (1-3 year restitution time). The risk for restitution times exceeding 3 years is low; < 1 % of the acceptance criteria for *Considerable* damage, and < 0.5 % of the acceptance criteria for *Serious* environmental damage (> 10 years restitution time). The dataset based on all data from all colonies is slightly lower with 4 % of the acceptance criteria for *Moderate* environmental damage.

Table 6-5 *Seasonal environmental risk calculation for Common guillemot from the different colonies; Bjørnøya, Hornøya, Hjelmsøya and Sklinna, applying the set of acceptance criteria defined in Table 6-3. Min/Mod/Conc/Ser refers to the damage categories defined according to restitution time. The **Total population** refers to all colonies combined.*

	Part of the Risk Acceptance Criteria								
Species	Autumn					Winter			
	Min	*Mod*	*Conc*	*Ser*		*Min*	*Mod*	*Conc*	*Ser*
Total population	0.9 %	3.5 %	0.3 %	0.0 %		0.0 %	0.1 %	0.0 %	0.0 %
Bjørnøya	1.2 %	4.8 %	0.5 %	0.2 %		0.2 %	0.6 %	0.0 %	0.0 %
Hjelmsøya	0.0 %	0.0 %	0.0 %	0.0 %		0.3 %	1.1 %	0.0 %	0.0 %
Hornøya	0.6 %	2.6 %	0.3 %	0.0 %		0.0 %	0.0 %	0.0 %	0.0 %
Sklinna	1.4 %	6.1 %	0.8 %	0.2 %		-	-	-	-
Maximum	***1.4 %***	***6.1 %***	***0.8 %***	***0.2 %***		***0.3 %***	***1.1 %***	***0.0 %***	***0.0 %***

🟩	10% - 20%
🟨	20% - 50%
🟧	50% - 100%
🟥	> 100%

6.2.3 Seabirds concentrated along the polar front

The results for a seabird population concentrated along the polar front are given in Table 6-6. The seabird species is assumed highest vulnerability (3) according to the methodology (see Chapter 4).

Calculated risk for a “population” concentrated in the area along the polar front is assessed to be conservative as no resources are either restricted to or distributed evenly throughout the defined area applied in the analysis (see Figure 5-1).

The calculated risk for this population is most critical in the winter season with 30 % of the acceptance criteria for *Serious* environmental damage (> 10 years restitution time). The risk level in all seasons is in the range 20-30 % of the acceptance criteria.

Table 6-6 *Seasonal environmental risk for a vulnerable seabird species concentrated along the polar front, given as percentage of a commonly used set of acceptance criteria used for this purpose on the NCS.*

Season	Part of the Risk Acceptance Criteria			
	Minor (< 1 year)	Moderate (1 - 3 years)	Considerable (3 - 10 years)	Serious (> 10 years)
Spring	4.4 %	23.7 %	22.4 %	29.4 %
Summer	4.6 %	22.3 %	16.8 %	19.2 %
Autumn	5.0 %	24.1 %	16.8 %	20.8 %
Winter	4.5 %	23.9 %	21.0 %	30.2 %

🟩	10% - 20%
🟨	20% - 50%
🟧	50% - 100%
🟥	> 100%

6.2.4 Ivory Gull

The results for the dynamic dataset for Ivory Gull following 20-50 % ice concentration are given in Table 6-7.

The overall risk for the population is approximately 2 % of the acceptance criteria for *Moderate* environmental risk (1-3 years restitution time).

Table 6-7 *Environmental risk for Ivory Gull concentrated in the marginal ice zone, given as percentage of the most commonly used acceptance criteria used for this purpose on the NCS.*

Season	Part of the Risk Acceptance Criteria			
	Minor (< 1 year)	Moderate (1 - 3 years)	Considerable (3 - 10 years)	Serious (> 10 years)
Winter/Spring	0.3 %	1.7 %	1.1 %	-

6.3 Summary and discussion of environmental risk

A summary of the risk calculations performed is given in Table 6-8 and Figure 6-8. Consequences and associated risk calculations affected by various assumptions linked to defining a population/colony:

1) Standardized “average” data commonly used in environmental risk analysis (*Seapop-data, pelagic seabirds*).

2) Specific, actual data describing distribution pattern of seabirds (Common guillemot) from different colonies (“populations”) (*gls-logger data*).

3) Dynamic data determined by environmental factors (in this case for *Ivory gull*, determined by the presence of the marginal ice zone), matched with specific oil drift modelling for the same period.

4) Very conservative data, restricting a population to a limited, static area throughout the whole year (*Polar front*).

The results show that the choice of datasets is of great importance when quantitatively evaluating environmental risk. In this case, the more uncertain data such as standardized, average distribution of seabirds as well as very conservative, uncertain and limiting choices such as the polar front-analysis, provide considerably higher calculated risk than more specific, less uncertain data (gls-data and dynamic data).

The dynamic seabird data for the marginal ice zone gives low risk (< 2 % of the acceptance criteria), as the potential for oil entering this zone is very limited. The data is also only relevant in a limited time of the year, when the sea ice is at its maximum southern orientation.

The gls-data shows that Common guillemot from several colonies uses the in the Barents Sea as wintering area, however mainly the south-western parts, and the potential for conflicts with the area at question in this analysis is limited (risk calculated to 6 % of the acceptance criteria).

Out of the “standard” datasets used in environmental risk analysis only seabirds at the open sea are at risk of oil exposure above the lower threshold of effects (one tonne per 10 × 10 km^2 area). This dataset is developed through the Seapop-program in 2013, based on counting data from boat transects, and modelling techniques. The dataset is described in more detail in Appendix C. The datasets do not describe the *specific* distribution of birds at different times, but rather an *average* distribution, based on several years of data. Based on these data the Black-legged kittiwake is most at risk, with up to 8 % of the acceptance criteria. The Black-legged kittiwake is the most numerous bird species in the world (Norsk Polarinstitutt, 2015). It is located in all Norwegian seas throughout the year. Telemetry studies indicates that a large part of the birds from European colonies uses the wintering areas outside Newfoundland in Canada (Seapop, 2015b). This could imply an overestimate of the consequences and risk in particular in the winter season, as the Barents Sea-population is assumed 100 % present in this season in the dataset used. However, due to a 15-30 % decrease in the period 1980-2009 the Svalbard-population it is listed at *near threatened* in the Norwegian Red list (Artsdatabanken, 2010), and care should be taken.

The Polar front is the area where cold Artic water meets the warmer Atlantic water. The front area formed has a rather distinct temperature and salinity gradient. On the Atlantic side of the Polar front the water does not freeze, but on the Arctic side it does. In parts of the year the Polar front is therefore concurrent with the ice edge (or could be further north) (Olje- og enegidepartementet, 2012). The environmental risk analysis for (species connected to) the Polar front area is based on the defined *area of particular environmental vulnerability*. The calculated environmental risk for the population restricted to the Polar front is 30 % of the acceptance criteria for *Serious* environmental damage. However, the following assumptions should be questioned and bore in mind when assessing the environmental risk based on this dataset:

- This area is located south of the BaSEC area regardless of previous information (Olje- og enegidepartementet, 2012) and (HI, 2012) indicating that the the polar front is north of the area.
- The area is assumed static, but should be variable due to differences in the balance between the Atlantic and Arctic water. The front area bound by the sea bed topography in the west and north (HI, 2012).
- The area is known to be an area of high biological productivity and bear a high density of seabirds and other natural resources. In the analysis it is assumed the presences of a full population evenly spread out in a smaller part of the front area. As add on to this conservatism it is assumed that the present population is of high vulnerability (vulnerability index 3).

Table 6-8 *Summary of environmental risk calculations for the different VEC-datasets for blowout from the "BaSEC well". The calculations are done seasonally, and the risk is given as percentage of the operation specific acceptance criteria most commonly used for this purpose on the NCS. The results are illustrated in Figure 6-8.*

Season	VEC dataset	Minor (< 1 year)	Moderate (1 - 3 years)	Considerable (3 - 10 years)	Serious (> 10 years)
Spring	**Pelagic seabirds**	1.2 %	5.0 %	0.3 %	0.0 %
	C. guillemot - gls-data	-	-	-	-
	Ivory gull	0.3 %	1.7 %	1.1 %	0.0 %
	Polar front	4.4 %	23.7 %	22.4 %	29.4 %
Summer	**Pelagic seabirds**	1.8 %	7.1 %	0.1 %	0.0 %
	C. guillemot - gls-data	-	-	-	-
	Ivory gull	-	-	-	-
	Polar front	4.6 %	22.3 %	16.8 %	19.2 %
Autumn	**Pelagic seabirds**	2.1 %	8.2 %	0.2 %	0.0 %
	C. guillemot - gls-data	1.4 %	6.1 %	0.8 %	0.2 %
	Ivory gull	-	-	-	-
	Polar front	5.0 %	24.1 %	16.8 %	20.8 %
Winter	**Pelagic seabirds**	1.4 %	5.9 %	0.3 %	0.0 %
	C. guillemot - gls-data	0.3 %	1.1 %	0.0 %	0.0 %
	Ivory gull	-	-	-	-
	Polar front	4.5 %	23.9 %	21.0 %	30.2 %

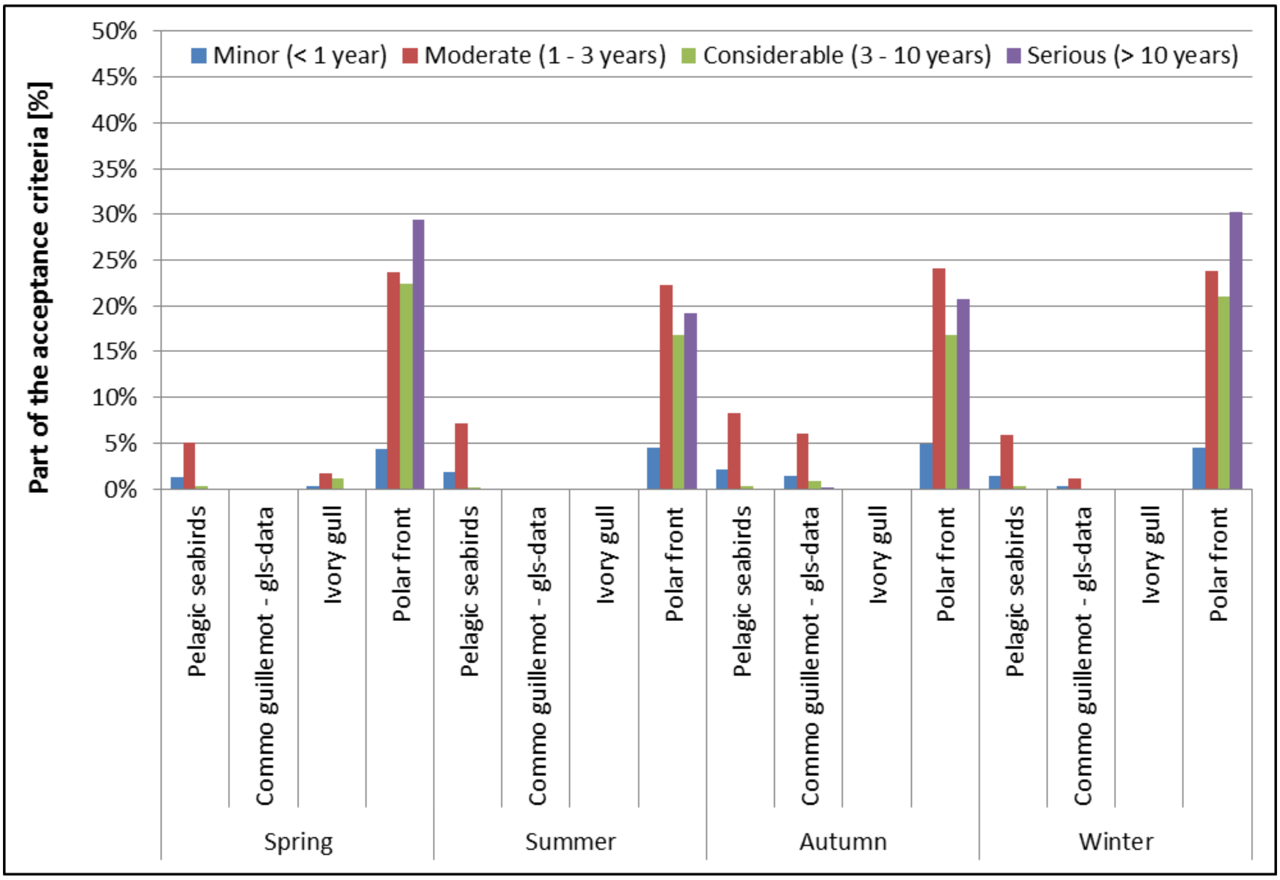


Figure 6-8 *Summary of environmental risk calculations for the different VEC-datasets for blowout from the "BaSEC well, given as percentage of the operation specific acceptance criteria most commonly used for this purpose on the NCS, in each season.*

7 CONCLUSIONS

The aim of the analysis was to identify potential environmental impacts from an oil blowout from a potential drilling location in the Barents Sea south-east. The location at question is in block 7435/9 in the most remote area within the opened acreage of the Barents Sea, approximately 380 km from the nearest land (the Hopen island). The environmental risk assessment is performed as a damage-based analysis, in accordance with the Norwegian oil and gas (formerly OLF) guideline for environmental risk analyses for petroleum activities on the Norwegian Continental Shelf (OLF, 2007b). The defined situation of hazard and accident (DSHA) for the activity is assumed to be an oil blowout during drilling. The release path following a blowout may be through open hole, drill pipe and annulus, each with associated blowout rates and a corresponding probability. To determine the associated risk level a generic blowout frequency for a wildcat exploration well is used; $1.41*10^{-4}$ per well. It is assumed the drilling operation is executed with the use of a semi-submersible drilling rig, and the probability distribution between surface and subsea blowout is set to 25 % / 75 % (Solberg, 2015). The estimated blowout rates vary from 800 to 5000 Sm^3/day for topside blowout and from 400 to 4000 Sm^3/day for subsea blowouts. The maximum duration is estimated to 84 days (time for mobilizing and drilling a relief well to stop the blowout).

The environmental risk analysis was done by combining oil drift modelling with various environmental resource data. Data on sea ice concentrations is implemented in the oil spill model; the SINTEF OSCAR model. The model uses daily mean ice concentrations for the period 1998-2005, along with 4 × 4 km currant data and 75 × 75 km resolution wind data. The Skrugard crude oil (871 kg/Sm^3) was used as reference oil in the modelling.

The oil spill trajectory modelling has proved that the potential effects will most likely be limited to the open sea areas and resources present at the sea surface during certain periods of the year. The probabilities for oil drifting to shore are extremely small (<0.5 % probability with a minimum of 40 days drift time). The nearest shoreline is Hopen and the south-eastern parts of Spitsbergen (Svalbard).

The analysis of potential oil pollution in the marginal ice zone is only relevant in the late winter/early spring when the polar drift ice is at its maximum. This analysis indicates that the prevailing weather conditions affecting the position of the marginal ice zone (≥15 % concentration) also affects the drift and distribution of surface oil. This means that surface oil is most likely to drift in the same direction as the sea ice; drifting north when the ice withdraws in the northern direction and south when the ice expands in the southern direction. However, this will be dependent on the sea ice concentrations. One can expect that ice concentrations exceeding a certain level will behave differently, and to a lesser degree be determined by the forces acting on sea surface oil.

Oil hit probability in partially ice infested areas indicates very limited overlap (2 out of 117 simulations) between oil and ice (concentration ≥ 15 %) 50 km to100 km areas north of the release location. At 150 km north of the release location no overlap is observed. The drift time to these areas varies between 14 and 24 days.

Regardless of the likelihood, at rather rare weather conditions the sea ice may move as far south as to cover the actual release location, causing the oil to be trapped within/underneath the ice. In such cases one can expect natural resources associated with the marginal ice zone, such as Ivory gull and a number of different marine mammal species, to be particularly vulnerable. The possible effects of oil in the marginal ice zone habitats have been further explored through dynamic modelling of consequences for Ivory gull.

The datasets on environmental resources included in the quantitative analysis are seabirds at the open sea and in coastal areas (Seapop, 2013 and 2012), marine mammals in coastal areas (DN & HI, 2007), DNV GL developed dynamic datasets for a species in the marginal ice zone (Ivory gull), gls-logger data for Common Guillemot, and DNV GL prepared dataset for species with a strong connections to the Polar front area. The different datasets are based on different assumptions; whereas the Seapop-data for pelagic seabirds are developed from several years of counting data, and modelled to give an "average" distribution covering the total Barents Sea area, the gls-logger data are actual, site-specific data of the location of this seabird species at a certain time of the year. The other difference in these two datasets are the definition of a "population", whereas the Seapop-data for pelagic seabirds defines all birds in the Barents Sea as one population, the gls-data allows us to regard birds from each of the different colonies as separate "populations". The two last types of datasets are very different. The dataset for Ivory gull is dynamic, following the marginal ice zone, as is assumed in real life, while the Polar front-dataset is static, assuming no variation in the presence of the Polar front or in the presence of natural resources following the Polar front. Out of the two assumptions it is safe to say that the dynamic data is best fitted to describe the actual processes and variations in the environment.

The environmental risk analysis has demonstrated that pelagic seabirds are the dimensioning resource with regards to risk within the study area. Resources with a strong connection to the Polar front areas are likely to be more concentrated within limited areas, with a potential for higher population losses given oil exposure, compared to widely distributed seabirds (Seapop, 2013). It is chosen a rather conservative approach to give an idea of the effects in the Polar front areas; assuming a seabird population of highest vulnerability (3) evenly distributed in a static Polar front area from the east of Svalbard to the sea areas approaching the Russian maritime boarder. This dataset gives the highest calculated environmental risk in the winter season with approximately 30 % of the acceptance criteria for *Serious* environmental damage (> 10 years restitution time). In comparison the standard seabird datasets (Seapop, 2013) gives a calculated risk of maximum 8 % of the acceptance criteria for *Moderate* environmental damage (1-3 year restitution time), in the autumn season. The Black-legged Kittiwake is the species that seems most likely to be affected at the open sea. The risk for the breeding populations of Common guillemot based on the gls-logger data is 6 % of the acceptance criteria for *Moderate* environmental damage, calculated for the Sklinna colony.

Ivory gull is associated with the marginal ice zone at 20-50 % ice concentration all year round, as well as being a threatened bird species. It is assumed that the full population is evenly distributed in the 20-50 % ice concentration area east of Svalbard. The analysis is only considered relevant in the winter/spring season as that is the period with potential for oil entering the marginal ice zone. The consequences are modelled for all spill rates following a topside blowout, and for expected blowout duration of 14 days. Only 1-2 out of 33 simulations gave a populations loss exceeding 1 % for Ivory gull. The maximum population loss was slightly increasing with increasing blowout rate (maximum 9.1 % population loss). Taking the results one step further into risk calculations considering the blowout frequency and the *normal* acceptance criteria, the overall risk was found to be approximately 2 % of the acceptance criteria for *moderate* environmental risk (1-3 years restitution time). The simulations affecting the Ivory gull in the marginal ice zone may also affect other resources such as marine mammals; i.e. different seal species and individuals of polar bears. Seals are though less vulnerable to oil pollution than seabirds, but also more stationary, which could mean a higher risk of exposure if oil should drift into the marginal ice zone. Possible effects on polar bears are expected to be on an individual level.

In this case, the analysis has proved that using specific data (as dynamic data for Ivory gull and site specific data for Common guillemot) gives lower risk, than by limiting the analysis to more *general* (as the average distribution of seabirds in the open sea represents), and *conservative* assumptions (limiting the population to a restricted area).

Based on the output from this study DNV GL is of the opinion that using a dynamic approach linking oil drift simulations and resource data/ice data in time and place provides a higher degree of reliability describing potential environmental effects compared to the use of static data/information. It is therefore recommended that further work is carried out within this field, developing dynamic distribution datasets for natural resources located in Norwegian waters, not limited to the marginal ice zone.

8 REFERENCES

Anker-Nilssen, T. (1987). Metoder til konsekvensanalyser olje/sjøfugl. - Viltrapport 44 (pp. 114 s).

Anker-Nilssen, T. (1994). Identifikasjon og prioritering av miljøressurser ved akutte oljeutslipp langs norskekysten og på Svalbard. - NINA Oppdragsmelding 310 (pp. 20). Trondheim: Norsk Institutt for Naturforskning.

Anon. (1979a). Acute Toxicity Test of API 78-3 No. 2 Home Heating oil (10% Cat). Elars Bioreserch Laboratories, Inc. Project No. 1443. . *American Petroleum Intitute, Med. Res. Publ. 2732773, 52p.*

Anon. (1979b). Acute Toxicity Test of API 78-4 No. 2 Home Heating oil (50% Cat). Elars Bioreserch Laboratories, Inc. Project No. 1443. . *American Petroleum Intitute, Med. Res. Publ. July 17, 1980, 52p.*

Anon. (1980a). Acute Toxicity Test of API 78-2 No. 2 Home Heating oil (30% Cat). Elars Bioreserch Laboratories, Inc. Project No. 1443. . *American Petroleum Intitute, Med. Res. Publ. 2732771, 48p.*

Anon. (1980b). Acute Toxicity Test of API 78-6 No. 6 Heavy Fuel Oil (API Gravity 11,7/2,7% S). Elars Bioreserch Laboratories, Inc. Project No. 1443. . *American Petroleum Intitute, Med. Res. Publ. 2732814, 47p.*

Anon. (1980c). Acute Toxicity Test of API 78-7 No. 6 Heavy Fuel Oil (API Gravity 17,1/0,8% S). Elars Bioreserch Laboratories, Inc. Project No. 1443. . *American Petroleum Intitute, Med. Res. Publ. 2732774, 45p.*

Anon. (1980d). Acute Toxicity Test of API 79-2 No. 6 Heavy Fuel Oil (API Gravity 5,2/1,2% S). Elars Bioreserch Laboratories, Inc. Project No. 1443. . *American Petroleum Intitute, Med. Res. Publ. 2732813, 52p.*

Arctic Pilot. (2004). Admiralty Sailing Directions, Iceland, Mayen, Bjørnøya, Svalbard, and the east coast of Greenland together with the adjacent seas, Volume II.

Artsdatabanken. (2010). Nasjonal kunnskapskilde for biologisk mangfold. Norske Rødliste for arter 2010., from http://www.artsdatabanken.no

Barrett, R. T. L., S.-H., Anker-Nilssen, T. (2006). The status of breeding seabirds in mainland Norway. Atlantic Seabirds 8(3): 97-126.

BirdLife International. (2014). http://www.birdlife.org/datazone/sitefactsheet.php?id=3198.

Bjørge. (2008). Notat i epost fra Arne Bjørge (HI) til Odd Willy Brude (DNV). 28.01.2008.

Bjørge, A., Øien, N., & Fagerheim, K.-A. (2007). Abundance of Harbour Seals (Phoca vitulina) in Norway Based on Aerial Surveys and Photographic Documentation of Hauled-Out Seals During the Moulting Season, 1996 to 1999. *Aquatic Mammals, 33*(3), 7.

Brude, O. W., Systad, G. H., Moe, K. A., & Østby, C. (2003). ULB Delutredning – studie7b. Uhellsutslipp til sjø. Miljøkonsekvenser på sjøfugl, sjøpattedyr, strand, iskant mv. Alpha miljørådgivning/Norsk institutt for naturforskning rapport nr. 1157-01 revisjon 02b.

Christensen-Dalsgaard, S., Bustnes, J. O., Follestad, A., G.H., S., Eriksen, J. M., S.-H., L., & Anker-Nilssen, T. (2008). Tverrsektoriell vurdering av konsekvenser for sjøfugl. Grunnlagsrapport til en helhetlig forvaltningsplan for Norskehavet. – NINA Rapport 338. (pp. 161 s).

Derocher, A. E. (1996). Population estimation and monitoring of polar bears in the Svalbard area: problem analysis. Norsk Polar Institute Internal Report. 1996:1-26.

DN & HI. (2007). Helhetlig forvaltningsplan for Norskehavet: Arealrapport med miljø- og naturressursbeskrivelse. Fisken og Havet 6-2007. 156 s.

DN & HI. (2010). Faglig grunnlag for en forvaltningsplan for Nordsjøen og Skagerrak: Arealrapport. Fisken og havet nr. 6/2010. TA-nr. 2681/2010. .

DNV. (2006). MIRA revisjon 2005. Rapport til OLF. DNV rapport nr. 11466, rev. 01. (pp. 41 s).

DNV. (2008). Om miljørisiko på fiskebestander. DNV rapport nr. 19538. Rev 01. Rapport for Oljeindustriens Landsforening.

DNV & SINTEF. (2010). Petroleumsvirksomhet. Oppdatering av faglig grunnlag for forvaltningsplanen for Barentshavet og områdene utenfor Lofoten (HFB). Konsekvenser av akutt utslipp for fisk.

DNV GL. (2015a). OIL SPILL RISK ASSESSMENT AND RESPONSE RELATED TO EXPLORATION DRILLING I BARENTS SEA SOUTH-EAST

Oil Spill Contingency Analysis *in prep.*

DNV GL. (2015b). Oil spill risk assessment and response related to exploration drilling in the Barents Sea South-East. Statusdocument; BaSEC-project report.

DNV GL & Akvaplan niva. (2014). Development of methodology for calculations of environmental risk for the marginal ice zone – A joint project between Akvplan-niva and DNV GL. *Report no.: 2014-0545, rev00., Document no.: 18L9BD0-6.*

Engelhardt, F. R. (1982). Hydrocarbon metabolism and cortisol in balance in oil-exposed ringed seal, Phoca hispida. .

Engelhardt, F. R. (1987). Assessment of the vulnerability of marine mammals to oil pollution. . *Fate and effects of oil in marine ecosystems.*

Eriksen, E., Gjøsæter, H., Bakkeplass, K., & Alvarez, J. (2006). Estimation of capelin larval indices using GIS.

Fauchald, P. (2011). Sjøfugl i åpent hav. Utbredelsen av sjøfugl i norske og tilgrensende havområder. NINA Rapport Nr. 786.

Fauchald, P., Tveraa, T., Bårdsen, B.-J., & Langeland, K. (2005). Utbredelse av sjøfugl i Norskehavet og Barentshavet. NINA rapport 64. (pp. 35 s).

Frost, K. F., & Lowry, L. F. (1993). Assessment of injury to harbor seals in Prince William Sound, Alaska, and adjacent areas following the Exxon Valdez oil spill. State- Federal Natural Resource Damage Assessment, Marine Mammals Study No. 5. .

Føyn, L., von Quilfeldt, C. H., & Olsen, E. (2002). Miljø- og resursbeskrivelse av området Lofoten – Barentshavet. Fisken og Havet, nr. 6 – 2002.

Geraci, J. R., & Smith, T. G. (1976). . Direct and indirect effects of oil on ringed seals (Phoca hispida) of the Beaufort Sea. *J. Fish. Res. Board Can., 33*, 1976-1984.

Geraci, J. R., & St. Aubin, D. J. (1987). Effects of offshore oil and gas development on marine mammals and turtles. Chapter 12, pp. 587-617 in "Long-term environmental effects of offshore oil and gas development" (D.F. Boesch & N.N. Rabalais, eds.). Elsevier Applied Science.

Geraci, J. R., & St.Aubin, D. J. (1990). Sea mammals and oil. Confronting the risks. (pp. 282).

Gilg, O., Strøm, H., Aebischer, A., Gavrilo, M. V., Volkov, A. E., Miljeteig, C., & Sabard, B. (2010). Post-breeding movements of northeast Atlantic ivory gull Pagophila eburnea populations. *Journal of Avian Biology, 41*(5), 532-542. doi: 10.1111/j.1600-048X.2010.05125.x

Hamre, J. (1994). Biodiversity and exploitation of the main fish stocks in the Norwegian-Barents Sea ecosystem. Biodivers Conserv 3:473-492.

Hansen, D. J. (1985). The potential effects of oil spills and other chemical pollutants on marine mammals occurring in Alaskan waters. Rep. MMS 85-0031. U.S. Dept. of the Interior, Minerals Manage. Serv., Alaska outer continental shelf reg., Anchorage. .

Havforskningsinstituttet. (2014). http://www.imr.no/temasider/fisk/torsk/polartorsk/nb-no

Havforskningsinstituttet. (2015). Kysten - Ressurser i åpne vannmasser.

Havforskningsinstituttet, N. P., Miljødirektoratet, Norsk institutt for naturforskning. (2010). Forvaltningsplan Barentshavet - rapport fra overvåkningsgruppen 2010. Fisken og havet, særnummer, 1b-2010.

Heggberget, T. M., & Moseid, K. E. (1989). Oter og olje. Rapport til olje og energidepartementet fra prosjektet oter og olje i 1989., *NINA oppdragsmelding 21: 1-13.*

HI. (2010). Havforskningsinstituttet, Norsk Polarinstitutt, Miljødirektoratet, Norsk institutt for naturforskning - Forvaltningsplan Barentshavet - rapport fra overvåkningsgruppen 2010. *Fisken og havet, særnummer, 1b-2010.*

HI. (2012). Kunnskap om marine naturressurser i Barentshavet sørøst. Konsekvensutredning for Barentshavet sørøst. Utarbeidet på oppdrag fra Olje- og energidepartementet. Rapport fra Havforskningen, 12-2012.

Hillebrand, H. (2004). On the generality of the latitudinal diversity gradient. *Am Nat, 163*(2), 192-211.

Hjermann, D., Melsom, A., Dingsør, G., Durant, J., Eikeset, A., Roed, L., . . . Stenseth, N. (2007). Fish and oil in the Lofoten-Barents Sea system: synoptic review of the effect of oil spills on fish population. MARINE ECOLOGY PROGRESS SERIES Mar Ecol Prog Ser Vol. 339: 283-299, 2007.

Jensen, B. M. (1996). An overview of exposure to, and effects of, petroleum oil and organochlorine pollution in Grey seals (Halichoerus grypus). The science of the Total Environment, 186: 109-118. Progress in Oceanography 71 (2006) (pp. 446-477).

Jensen, B. M. (2008a). Effekter på oter og mink. from http://biologi.no/Oljeforurensing/effekter_pa_oter_mink.htm

Jensen, B. M. (2008b). Effekter på sel. from http://biologi.no/Oljeforurensing/effekter_pa_sel.htm

Johansen, Ø. (2006). Implementation of the near-field module in the ERMS model, Technical report, SINTEF.

Klima - og Miljødepartementet. (2015). Oppdatering av forvaltningsplanen for Barentshavet og havområdene utenfor Lofoten med oppdatert beregning av iskanten. *Meld.St.20 (2014-2015)*.

Kovacs, K. M., Haug, T., & Lydersen, C. (2009). Marine mammals of the Barents Sea. In E. Sakshaug, G. Johnsen and K.M. Kovacs (Eds.), Ecosystem Barents Sea.

Kålas, J. A., Viken, Å., Henriksen, S., & Skjelseth, S. (2010) Norsk Rødliste for arter 2010. *The 2010 Norwegian red list for species* (pp. 480). Trondheim: Artsdatabanken.

Lipscomb, T., Harris, R., Rebar, A., Ballachey, B., & Haebler, R. (1994). Pathology of the sea otters. Pp 265-279 in: "Marine mammals and the Exxon Valdez", Loughlin, T.R. (ed.). Academic Press, London.

Lloyd's Register Consulting. (2015). Blowout and well release frequencies based on SINTEF offshore blowout database 2014. *Report no: 19101001-8/2015/R3*(Draft A).

Loeng, H., & Drinkwater, K. (2007). Deep-sea reserach II 54 2478-2500. An overview of the Barents and Norwegian Seas and their response to climate variability.

Lorentsen, S.-H., & Christensen-Dalsgaard, S. (2009). Det nasjonale overvåkingsprogrammet for sjøfugl. Resultater til og med hekkesesongen 2008. . *NINA Rapport Nr. 439*.

MI. (2012). Isdata fra Meteorologisk institutt. Statistikk for 2001-2011.

Moe et al. (1993). Skadevirkninger av akutte oljesøl. Marint miljø. SFT-rapport 93:31. Statens forurensningstilsyn.

MRDB. (2010). Marin Ressurs Data Base. from http://www.mrdb.no

Narasimhan, M. J. J., & Ganla, V. G. (1967). Experimental studies on kerosene poisoning. Acta. Pharmacol. (Kobenh.) (Vol. 25, pp. 214-224).

NINA. (2008). Tverrsektoriell vurdering av konsekvenser for sjøfugl. Grunnlagsrapport til en helhetlig forvaltningsplan for Norskehavet. .

NINA v/Kjell E. Erikstad. (2015). Presentasjon på Seapop-seminaret april 2015. Sårbarhet av sjøfugl til akutt oljeforurensning -Utvikling av ny metodikk basert på logger teknologi og oljesimuleringer. http://www.seapop.no/opencms/export/sites/SEAPOP/no/filer/pdf/seapop-seminar-2015/15-Erikstad.pdf

Norsk olje og gass. (2014). Development of methodology for calculations of environmental risk for the marginal ice zone – A joint project between Akvplan-niva and DNV GL. . *Report No. 2014-0545*.

Norsk Polarinstitutt. (2012). Notat - Status for forekomst av isbjørn i Barentshavet SØ. Vongraven, D. 05.07.2012.

Norsk Polarinstitutt. (2015). Krykkje http://www.npolar.no/no/arter/krykkje.html

Norwegian Biodiversity Information Centre. (2010). IUCN red list, 2013.

Norwegian Polar Institute. (2011). Bjønøya's wildlife.

OLF. (2007a). Metode for miljørettet risikoanalyse (MIRA) - revisjon 2007. *OLF rapport*.

OLF. (2007b). Metode for miljørettet risikoanalyse (MIRA) - revisjon 2007. .

OLF. (2008). Metodikk for miljørisiko på fisk ved akutte oljeutslipp. DNV rapport 2007-2075. (pp. 87s).

Olje- og enegidepartementet. (2012). Konsekvensutredning etter petroleumsloven. Åpningsprosess for petroleumsvirksomhet i Barentshavet sørøst.

Peterson, C. H. (2001). The “Exxon Valdez” Oil Spill in Alaska: Acute, Indirect and Chronic Effects on the Ecosystem. *Adv. Mar. Biol, 39* 1-103.

Piatt, J. F., Lensink, C. J., Butler, W., Kendziorek, M., & Nysewander, D. R. (1990). Immediate impact of the “Exxon Valdez” oil spill on marine birds. - Auk 107: 387-397.

RC Consultants, & NINA. (1999). Beskrivelse av influensområdet til havs og til lands 1999 - Temarapport 3.

Rowe, L. D., Dollahite, J. W., & Camp, B. J. (1973). Toxicity of two crude oil and of kerosene to cattle. . *J. Am. Vet. Med. Assoc. 162: 61-66.*

Saksen, K., & Bakken, V. (1985). Important moulting areas for seabirds in Svalbard. Norsk Polarinstitutt *Meddelelser 135:*, 59-66.

Seapop. (2011). Rådata innhentet for konsentrasjoner av kystnære sjøfuglarter for Svalbard og Bjørnøya.

Seapop. (2012). Rådata innhentet for konsentrasjoner av kystnære sjøfuglarter fra Norsk Institutt for Naturforskning ved Geir Systad.

Seapop. (2013). Sjøfugl åpent hav. Utbredelsen av sjøfugl i norske og tilgrensende havområder.

Seapop. (2014). http://www.seapop.no/no/aktiviteter/bestandsstorrelser/bestandsstorrelser.html

Seapop. (2015a). http://www.seapop.no/no/metoder/kartlegging-hav/index.html

Seapop. (2015b). Krykkje http://www.seapop.no/no/utbredelse-tilstand/utbredelse/apent-hav/#krykkje

SFT & DN. (2000). Beredskap mot akutt forurensning. Modell for prioritering av miljøressurser ved akutte oljeutslipp langs kysten. (pp. 1765-2000).

Solberg, A., Bergsli, A. (2015). Input t the environmental risk assessment - Blowout scenario anlaysis - exploration well scenarios in area A for A23R (BaSEC). *Technical note*, 8.

St.Aubin, D. J. (1990). Physiologic and toxic effects on pinnipeds. . *Sea mammals and oil. Confronting the risks.*

Steen, H., Lorentzen, E., & Strøm, H. (2013). Winter distribution of guillemots (Uria spp.) in the Barents Sea. *141 Rapportserie Norsk Polarinstitutt*.

Stenevik, E. K., Huse, G., & Svendsen, E. (2005). Modellert fordeling av torske- og sildelarver langs norskekysten i perioden 1981-2004.: Havforskningsinstituttet.

Systad, G. H., & Bustnes, J. O. (1999). Fordeling av kystnære sjøfugler langs Finnmarkskysten utenom hekketida: Kartlegging ved hjelp av flytellinger. - NINA Oppdragsmelding 605 (pp. 1-66). Trondheim: Stiftelsen for naturforskning og kulturminneforskning.

Systad, G. H., & Strøm, H. (2012). Kunnskapsstatus Barentshavet sør - Sjøfugl i våre nordlige havområder *NINA rapport 877.*

Sætre, R. (1999). Strømforhold i øvre vannlag utenfor Norge. Havforskningsinstituttet (pp. 34).

University of Bremen. Daily Sea Ice Concentration Data (2003 –) prepared and made available by University of Bremen, http://www.iup.uni-bremen.de:8084/amsr2/index.html

Vikebø et al. (2009). from http://talos.nodc.no:8080/ncWMS/larve.html

Weslawski, J. M., Zajaczkowski, M., Wiktor, J., & Szymelfenig, M. (1997). Intertidal zone of Svalbard: 3. Littoral of a subarctic, oceanic island: Bjornoya. *Polar Biol. 18(1):*, 45-52.

Øksenvåg, J. H. C. (2012). Skrugard crude oil - weathering studies. Oil properties related to oil spill response. *SINTEF A22589*.

Øritsland, N. A. E., F.R.; Juck, F.A.; Hurst, R.J. and Watts, P.D. (1981). Effects of crude oil on polar bears. Environmental studies 24, Northern Affairs Program, Department of Indian and Northern Affairs, Ottawa, Canada. 268 pp.

APPENDIX A

Method description - environmental risk

An environmental risk analysis is performed step by step in accordance to the industry guideline (OLF, 2007a) and carried out as a damage-based environmental risk analysis. A short description of the method is given in the following, but it is referred to the guideline for more supplementary information. For coastal habitats every 10 × 10 km grid cell is analysed within the influence area, which is also described in the guideline (OLF, 2007a).

Damage based environmental risk per year for drilling (time limited activity-*operation*) is calculated by Formula 1:

Formula 1:

$$f_{\mathit{damage\ (damage\ category)\ operation}} = f_{0\ (\mathit{operation})} \times p[\text{duration}] \times p[\text{hit}] \times p[\text{presence}] \times p[\text{damage}_{(\mathit{damagecategory})}]$$

where:

f_{damage} = probability (frequency) for damage within a given damage category.
f_0 = frequency for incident per operation
P_{hit} = probability for hit of a VEC in a 10 x 10 grid cell. given an incident.
P_{presence} = probability for presence of a VEC.
P_{damage} = probability for damage in a given damage category.

Seabirds and marine mammals

Environmental damage for populations of e.g. seabirds is estimated by calculating how large a part of the population is killed given by a possible oil spill. This is done by connecting the geographical distribution of seabirds; spread in 10 x 10 km grid cells, with the probability for oil pollution in the corresponding grid cells. The loss of individuals in each grid cell is estimated in accordance with the effect key shown in Table A-1 for seabirds and Table A-2 for marine mammals.

Table A-1 *Effect key for estimating fraction of birds affected within a 10 x 10 km grid cell, given exposure to oil (divided in four mass categories).*

Oil rate in 10 x 10 km grid cell	Effect key – Acute death		
	Individual vulnerability for VEC seabirds		
	V1	V2	V3
1-100 tonnes	5 %	10 %	20 %
100-500 tonnes	10 %	20 %	40 %
500-1000 tonnes	20 %	40 %	60 %
≥1000 tonnes	40 %	60 %	80 %

Table A-2 *Effect key for estimating fraction of marine mammal affected within a 10 x 10 km grid cell, given exposure to oil (divided in four mass categories).*

Oil rate in 10 x 10 km grid cell	Effect key – Acute death		
	Individual vulnerability for VEC marine mammals		
	V1	**V2**	**V3**
1-100 tonnes	5 %	15 %	20 %
100-500 tonnes	10 %	20 %	35 %
500-1000 tonnes	15 %	30 %	50 %
≥1000 tonnes	20 %	40 %	65 %

The lost share of the population is further used to characterize the seriousness of the environmental damage in four consequence categories. Each consequence category is given a theoretical restitution time:

Minor	*< 1 year theoretical restitution time*
Moderate	*1 - 3 year theoretical restitution time*
Considerable	*3 - 10 year theoretical restitution time*
Serious	*> 10 year theoretical restitution time*

The damage key (Table A-3) is based on information on species population dynamics as well as on modelling of restitution time for species with low reproduction potential (OLF, 2007a); (Barrett, 2006); (Lorentsen & Christensen-Dalsgaard, 2009).

For a population with a negative population trend there are two possibilities: The population is recovered more slowly because it is under stress, or the population is recovered more rapidly because of less competition within the population rendering the time to get back to the descending population line is shorter. In this analysis the first of these theories has conservatively been chosen.

For each of the oil drift simulations the damage is estimated for each grid cell in accordance to the reduction of the population and the defined damage key. The damage in all grid cells is then added up to represent the total damage on a population in accordance with the key for restitution time. Finally the environmental risk is compared to the *acceptance criteria*.

Table A-3 *Damage key for the probability distribution of theoretical restitution time by acute reduction of seabird- and marine mammal populations with low restitution potential (S3) (OLF, 2007a).*

Acute reduction of the stocks	Consequence category – Environmental damage Theoretical restitution time in year			
	Minor <1 year	**Moderate 1-3 years**	**Considerable 3-10 years**	**Serious >10 years**
1-5 %	50 %	50 %		
5-10 %	25 %	50 %	25 %	
10-20 %		25 %	50 %	25 %
20-30 %			50 %	50 %
≥ 30 %				100 %

Coastal habitats

The environmental risk for coastal habitats is calculated in accordance with the VEC habitat methodology (OLF, 2007a). For VEC habitats the environmental damage is estimated directly from the oil drift statistics in an area (e.g. a 10 × 10 km^2 grid cell), and the vulnerability of the habitat affected (vulnerability on habitat/ecosystem level). The environmental damage is expressed in terms of restitution time for the habitats. Restitution is achieved when the original plant- and animal life in the affected ecosystem is back on the same level as before the spill (natural variation taken into consideration), and the biological processes are working normally.

In the VEC habitat method the probability for environmental damage to the coastal habitats are calculated for all 10 × 10 km grid cells affected. The probability is estimated from the degree of exposure, the nature of coastal habitats and their vulnerability (Table A-4).

Table A-4 *Vulnerability indices for coastal habitats (exposed and protected coasts), (DNV, 2006).*

Classification	Degree of vulnerability	
	Exposed	**Protected**
Bare rock	1	1
Cliff	1	1
Boulder beach	1	2
Sandy beach	2	3
Rocky beach	1	3
Clay	2	3
No data	2	3
Man made	1	1
Sand dune	2	3

For each grid cell, information on the classification of the habitat and the length of each type of habitat forms the basis for the analysis. Each type of coastal habitat is given a vulnerability index V1, V2 or V3. The vulnerability indices are differentiated for exposed and protected coasts, and according to the type of substrate.

In early versions of the guideline the damage was estimated from the coast type with the highest vulnerability within each grid cell, independent of whether or not this vulnerability was dominant or not in that particular grid cell. With the latest methodology update (OLF, 2007a), however, the probability for damage in each vulnerability category is estimated separately for each grid cell.

The contribution from each vulnerability category is equal to the relative distribution of vulnerability categories within the grid cell. The probability for damage to the coast within each vulnerability index is then a product of the probability for oil in the four different oil mass categories, the part of the coast with vulnerability index 1, 2 or 3, and the respective probability distribution for the consequence categories shown in Table A-5. The total probability for damage in each grid cell is obtained by adding up the probability for each consequence category for the three different vulnerability indices.

Table A-5 *Damage key for the probability for damage to the coastline (DNV, 2006).*

Damage key for coastal types		Damage category - Theoretical restitution time			
Vulnerability	**Oil masses [tonnes]**	**Minor <1 year**	**Moderate 1-3 year**	**Considerable 3-10 year**	**Serious >10 year**
High (S3)	1-100	20 %	50 %	30 %	
	100-500	10 %	60 %	20 %	10 %
	500-1000		20 %	50 %	30 %
	>1000			40 %	60 %
Moderate (S2)	1-100	60 %	40 %		
	100-500	30 %	60 %	10 %	
	500-1000	10 %	60 %	30 %	
	>1000		40 %	50 %	10 %
Low (S1)	1-100	80 %	20 %		
	100-500	60 %	40 %		
	500-1000	40 %	50 %	10 %	
	>1000	20 %	40 %	40 %	

Fish

A quantification of possible consequences for fish as a result of accidental discharge of oil is based on the combination of exposure of hydrocarbons in the water column, and the biological effects of such an exposure on survival of eggs and larvae (the most sensitive/vulnerable life stage). Further it is assessed (statistically) what consequences a reduced survival of eggs/larvae will have on the year class recruitment and possibly also on the adult spawning stock biomass.

In this analysis a statistical approach is used looking at potential overlap between a large number of oil drift modelling simulations based on historical wind and current data, combined with a large number of distribution patterns for cod and capelin eggs and larva based on observed historical spawning data. The exposure is a result of the potential overlap of larva and water column concentrations of THC (including both dissolved fractions and oil droplets) exceeding the effect limit defined to be lethal or reduce survival.

Figure A-1 shows a general overview over the statistical approach in the method.

A study for OLF, performed by DNV, Institute of Marine Research (HI) and the University of Oslo, recommends the use of a dose-response correlation as a base for effect and damage calculations in this type of analyses. A dose-response correlation based on total hydrocarbon concentrations (THC from both dissolved oil and droplets) in the water column (OLF, 2008) is used in the calculations. The dose-response correlation starts at 100 ppb, which gives 1 % mortality, and goes up to 1 ppm which gives 100 % mortality for eggs/larvae.

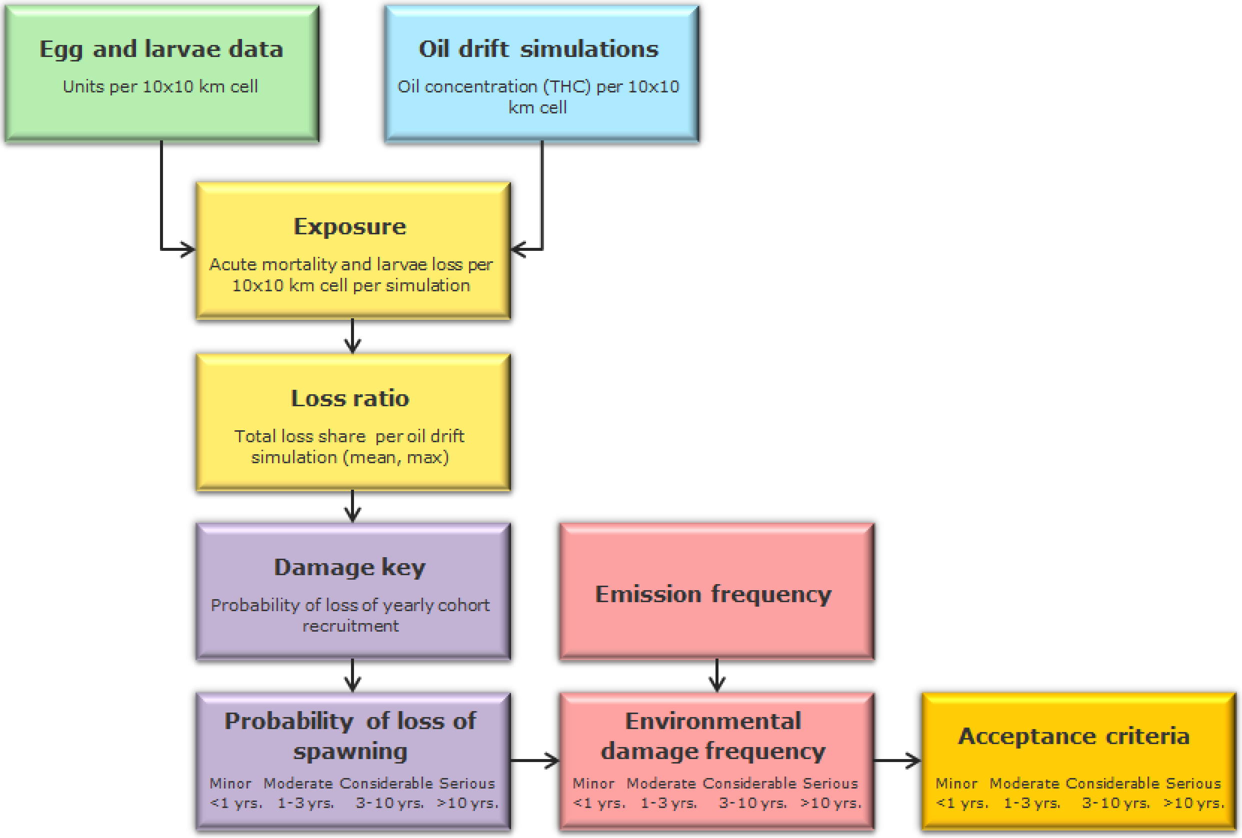


Figure A-1 *Overview over environmental risk methodology for quantification of impact on fish stocks related to accidental oil spills.*

The statistical approach with a lot of spill simulations will give a probability of different outcomes also related to the huge variation in distribution and drift pattern of fish larvae from year to year and during the spawning / larvae drift period. A range of uncertainties and challenges is given in such an approach, and some of the main challenges are:

- Good enough input data on the distribution of egg/larvae to ensure the variations both between years and through the larvae-drift period are considered.
- Good enough input data to be able to quantify exposure and effects in time and space (effect data and match between oil drift and larvae distribution).
- Variations in survival/mortality for larvae and how to ensure this in the model, and thus be able to say something about the effect on the recruitment of the year class.
- Effect on the spawning population as a result of reduction in the year class recruitment.

In a statistical approach it is possible to include variation in larvae survival by giving a sample space related to how much a loss of larvae will affect the loss of year class recruitment, i.e. the loss of those who would ideally survive and grow up. As an example one might add a possibility that the larvae exposed to oil has 50 % higher than average survival rate but also the same probability for 50 % lower than average survival rate. This gives different probabilities for different mortality on the year class based on the calculated mortality (%) of egg/larvae. The approach used includes a factor 10 in survival variation in accordance to recommendations in the method report for oil-fish (DNV, 2008), and gives probability for different outcomes as presented in Table A-6.

Table A-6 *Probability of loss of year class recruitment for different calculated mortalities of egg/larvae (OLF, 2008).*

Loss (%) in year class recruitment	**Mortality (%) for egg/larvae**						
	1 %	**2 %**	**5 %**	**10 %**	**20 %**	**30 %**	**50 %**
<1 %	50 %	10 %					
1 %	30 %	20 %	10 %				
2 %	15 %	40 %	20 %	10 %			
5 %	5 %	20 %	40 %	20 %	10 %	5 %	
10 %		10 %	20 %	40 %	20 %	10 %	5 %
20 %			10 %	15 %	40 %	15 %	10
30 %				10 %	15 %	40 %	15
50 %				5 %	10 %	20 %	40 %
100 %					5 %	10 %	30 %

The environmental risk for the spawning population is calculated as probability for a given restitution time as a consequence of the loss in year class recruitment, according to the “Ugland-model” for cod (Figure A-2). Loss and possible restitution time for capelin is calculated based on the methodology presented in ‘Oil & Fish- Barents Sea’ (Brude, Systad, Moe, & Østby, 2003).

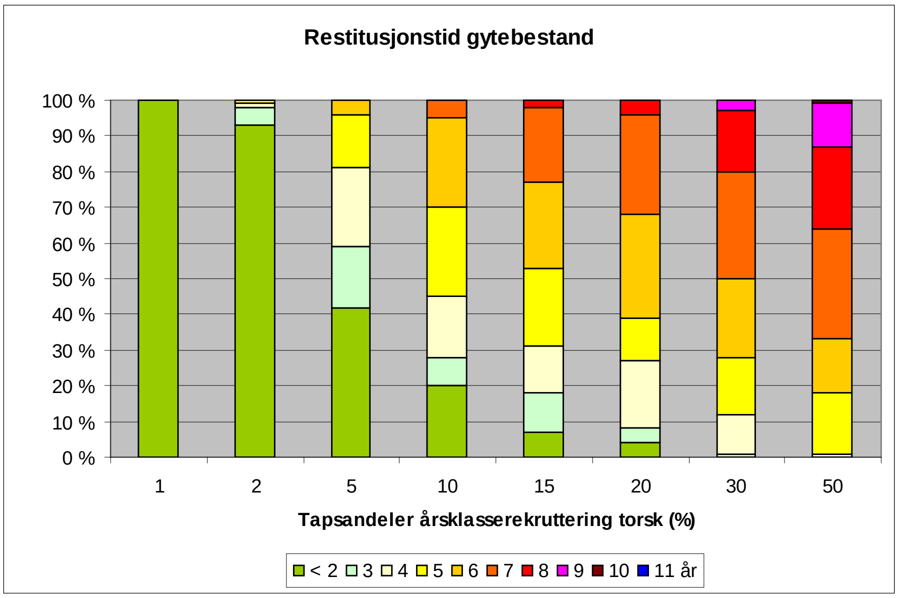


Figure A-2 *Estimated restitution time for spawning population of cod, as a consequence of different losses of year class recruitment. Based on the "Ugland-model".*

The marginal ice zone

Akvaplan-NIVA and DNV GL has collaborated on the development of a methodology for calculations of environmental risk for the marginal ice zone, on behalf of Norwegian Oil and Gas (Norsk olje og gass, 2014). The marginal ice zone (MIZ) was defined as sea ice of 10-30 % concentration. This differs from the newly updated definition of the marginal ice zone following the update of the Management plan for the Barents Sea (Klima - og Miljødepartementet, 2015). The methodology recommends using dynamic ice data in oil drift modelling, without limiting the marginal ice zone to certain concentrations, as is done in this project. In the SINTEF OSCAR model the statistical ice data from the hindcast archive (SVIM) is integrated. DNV GL follows the new recommendations and uses the ≥15 % ice concentration limit in the evaluations of results from the modelling.

The project of developing the methodology was executed in consultation with the Norwegian Polar Institute, the Norwegian Institute for Nature Research and the Institute for Marine Research. It was concluded that the existing *effect* and *damage keys* in the ERA methodology OLF, 2007) should be applicable also for calculating environmental risk in (partially) ice covered waters, but given a recommendation about certain adjustments of vulnerability indexes to a higher value for some species and periods.

For seabirds this includes the species Black-legged kittiwake, Ivory gull, Glaucous gull and Sabine's gull, while for marine mammals the Svalbard-population of Grey seal and several whale species is included. The species and the suggested vulnerability indexes in each month are listed in Table A-7. Out of the species listed only Black-legged kittiwake, Ivory gull, Glaucous gull and Grey seal are included in the quantitative analysis.

Table A-7 *Suggested monthly vulnerability indexes for species connected to the marginal ice zone in the Arctic.*

Species	*Jan*	*Feb*	*March*	*April*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Des*
Kittiwake	3	3	3	3	3	3	3	3	3	3	3	3
Ivory gull	3	3	3	3	3	3	3	3	3	3	3	3
Glaucous gull	2	2	2	2	3	3	3	3	2	2	2	2
Sabine's gull	2	2	2	2	3	3	3	3	2	2	2	2
Grey seal	2	2	2	2	2	3	3	3	2	2	2	2
White whale	2	2	2	2	2	2	2	2	2	2	2	2
Narwhale	2	2	2	2	2	2	2	2	2	2	2	2
Sperm whale				1	1	1	1	1	1	1		
Killer whale	2	2	2	2	2	2	2	2	2	2	2	2
Knølhval	2	2	2	2	2	2	2	2	2	2	2	2
Humpback whale	2	2	2	2	2	2	2	2	2	2	2	2
Bowhead whale	3	3	3	3	3	3	3	3	3	3	3	3

APPENDIX B

Consequence calculations for all species

Up on request.

APPENDIX C

Description of environment and natural resources – the Barents Sea

The following document presents a short review of the environment and natural resources inhabiting the Barents Sea. For a more extensive description of the regional resources, it is referred to ” Miljø- og ressursbeskrivelse av området Lofoten – Barentshavet” (Føyn et al., 2002). “Helhetlig forvaltningsplan for Lofoten og Barentshavet” (N. P. Havforskningsinstituttet, Miljødirektoratet, Norsk institutt for naturforskning, 2010) and the HI report “Kunnskap om marine ressurser i Barentshavet sørøst” (HI, 2012).

Physical environment

The Barents Sea is a shallow shelf sea where the Norwegian part constitutes about 1.4 million km^2, and has an average depth of 230 meters. The bottom topography is dominated by large banks (100-200 meters, e.g. Sentralbanken, Spitsbergenbanken and Storbanken) and deep channels (300-400 meters, e.g. Bjørnøyrenna) between the banks. The western part of the Barents Sea follows the steep continental slope against the Norwegian Sea.

The water masses in the Barents Sea are composed of warm, salty Atlantic water (temperature >3 °C, salinity>35) from the North Atlantic drift, cold Arctic water (temperature <0 °C, salinity<35) from the north and warm, but not very salty coastal water (temperature >3 °C, salinity<34.7) (Figure C - 1). Between the Atlantic and Polar waters, a front called the Polar front is formed. In the western parts of the sea (close to Bear Island), this front is rather clearly defined and stable from year to year, while in the east (towards Novaya Zemlya), it can be quite diffuse and its position can shift significantly from year-to-year. The Polar front is a place for considerable primary production during the spring- and summer season (Føyn et al., 2002). Similar growth/bloom occurs in the spring in a 20-50 km wide zone along the ice edge where melting of the ice create conditions for a stable surface layer and release of nutrients.

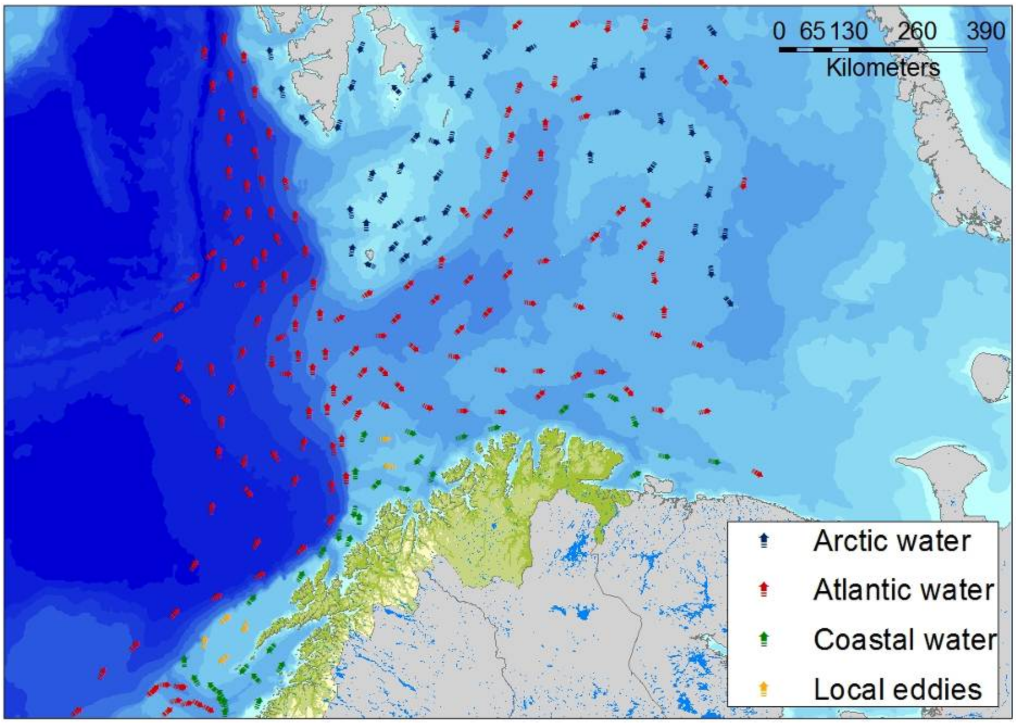


Figure C - 1 *Current pattern in the Barents Sea (Sætre, 1999).*

The marginal ice zone

The marginal ice zone (MIZ) is the transition zone between water and solid sea ice. In general the area is very dynamic with large variations in ice concentrations within short time. Wind and ocean currents towards the ice coverage may produce a solid ice edge, while wind and current in the opposite direction may cause a marginal ice zone stretching throughout large areas of different concentrations.

The MIZ is a nutrient-rich area in the Barents Sea. The ice distribution in the Barents Sea is affected by air temperature and the inflowing Atlantic water (m^3/s and core temperature). The melting of ice in the summer half year gives a surface layer of water with higher temperature, lower salt content and less dense than the underlying water. In the spring, when sunlight is no longer a limiting factor, there is a massive growth of plant plankton which forms a stable foundation for the food chain consisting of zooplankton, fish, seabirds and marine mammals. The MIZ retreats northward during summer, causing a progressive northbound growth. The ecosystem connected to the MIZ is of key importance for all life in the Barents Sea, and a potential acute oil spill affecting the area may cause serious consequences for the entire ecosystem.

The seasonal maximum ice coverage (of different concentrations) in the Barents Sea, based on statistics from 2001-2011 is shown in Figure C - 2 to Figure C - 4. It is important to highlight that the ice coverage is highly variable from year to year, and also within in a month/season. The areas surrounding the BaSEC well location is ice free most part of the year due to inflow of warmer Atlantic water (MI, 2012). The figures are however only for illustrative purposes, as a different set of dynamic ice data is included in the oil drift modelling.

There are several definitions of the MIZ and associated ice concentrations, for instance 15-30 %, 15-40 % and 10-30 % (http://seaiceatlas.snap.uaf.edu/glossary). In environmental risk analysis ice concentrations of 10 % is suggested applied (DNV GL & Akvaplan niva, 2014), based on the Norwegian Meteorological Institute's definition of ice concentrations < 10 % as open sea and > 10 % may influence the exposure scenarios to a certain degree compared to open sea analysis. In the original and updated management plan for the Barents Sea area the marginal ice zone is defined as 30 % probability for ≥15 % ice concentration (Klima - og Miljødepartementet, 2015). This level is used when evaluating potential oil masses and consequences for the marginal ice zone throughout the year.

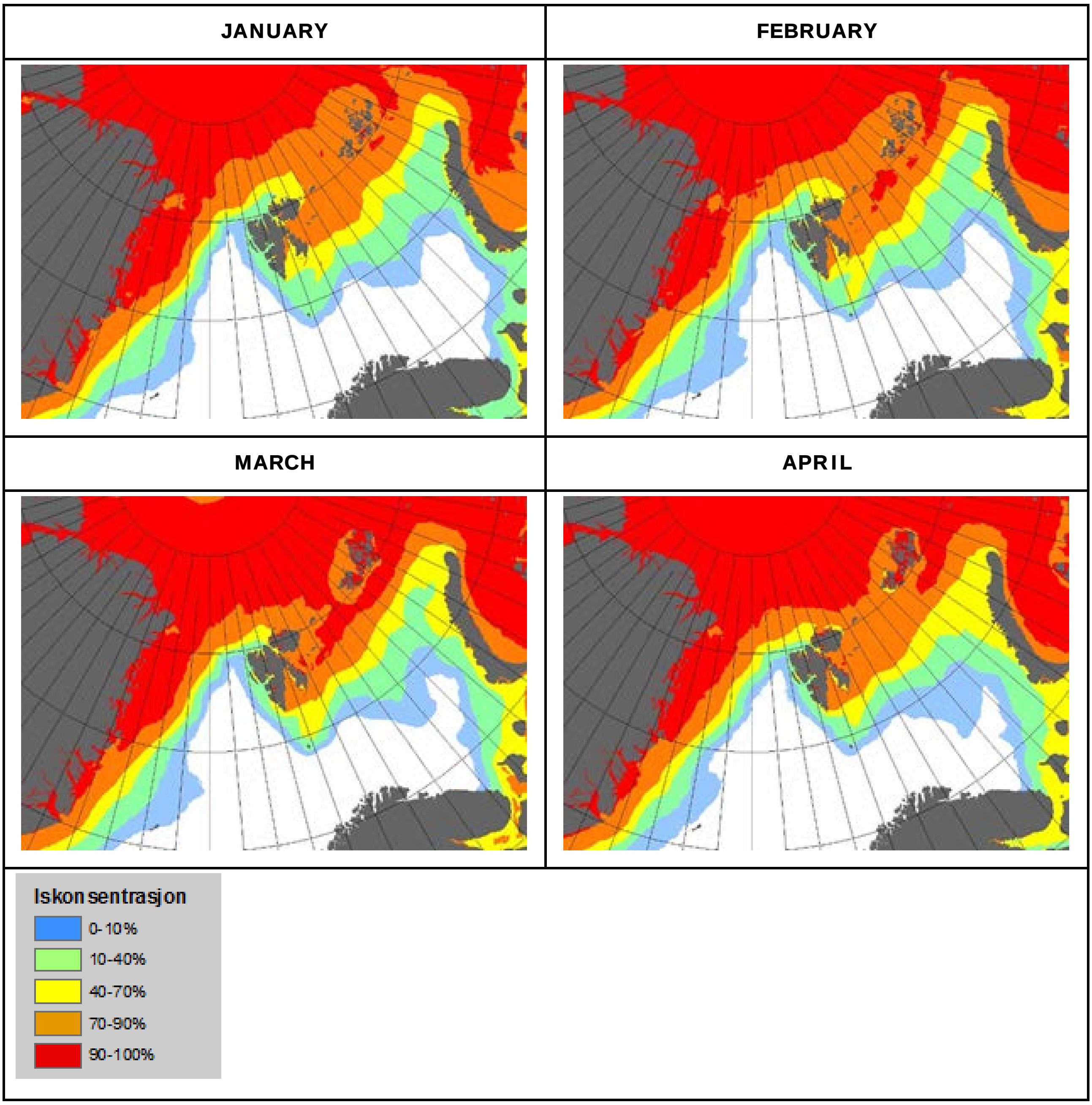


Figure C - 2 *Maps illustrating monthly (January-April) mean ice concentrations for the period 2001-2011 (MI, 2012).*

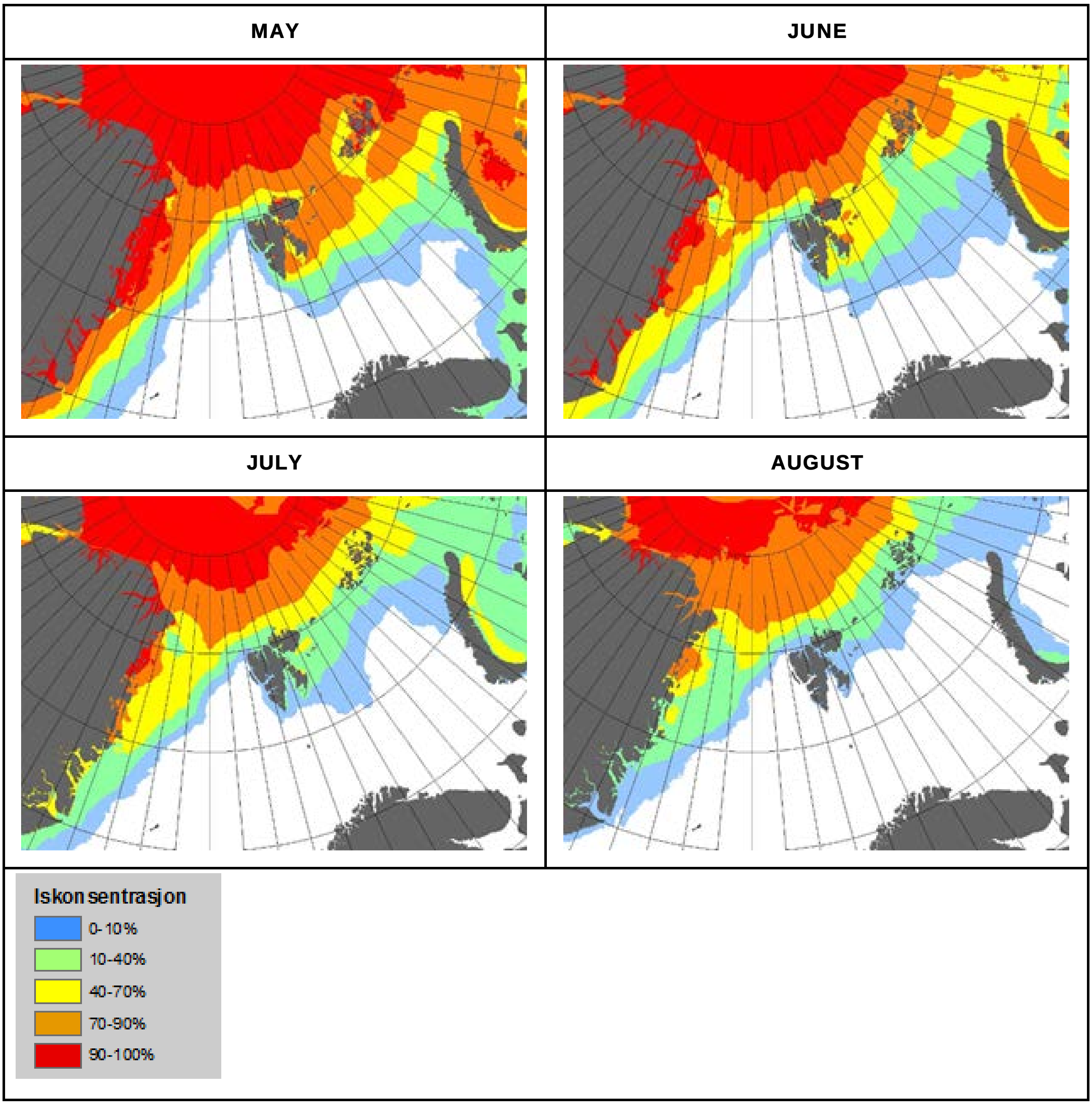
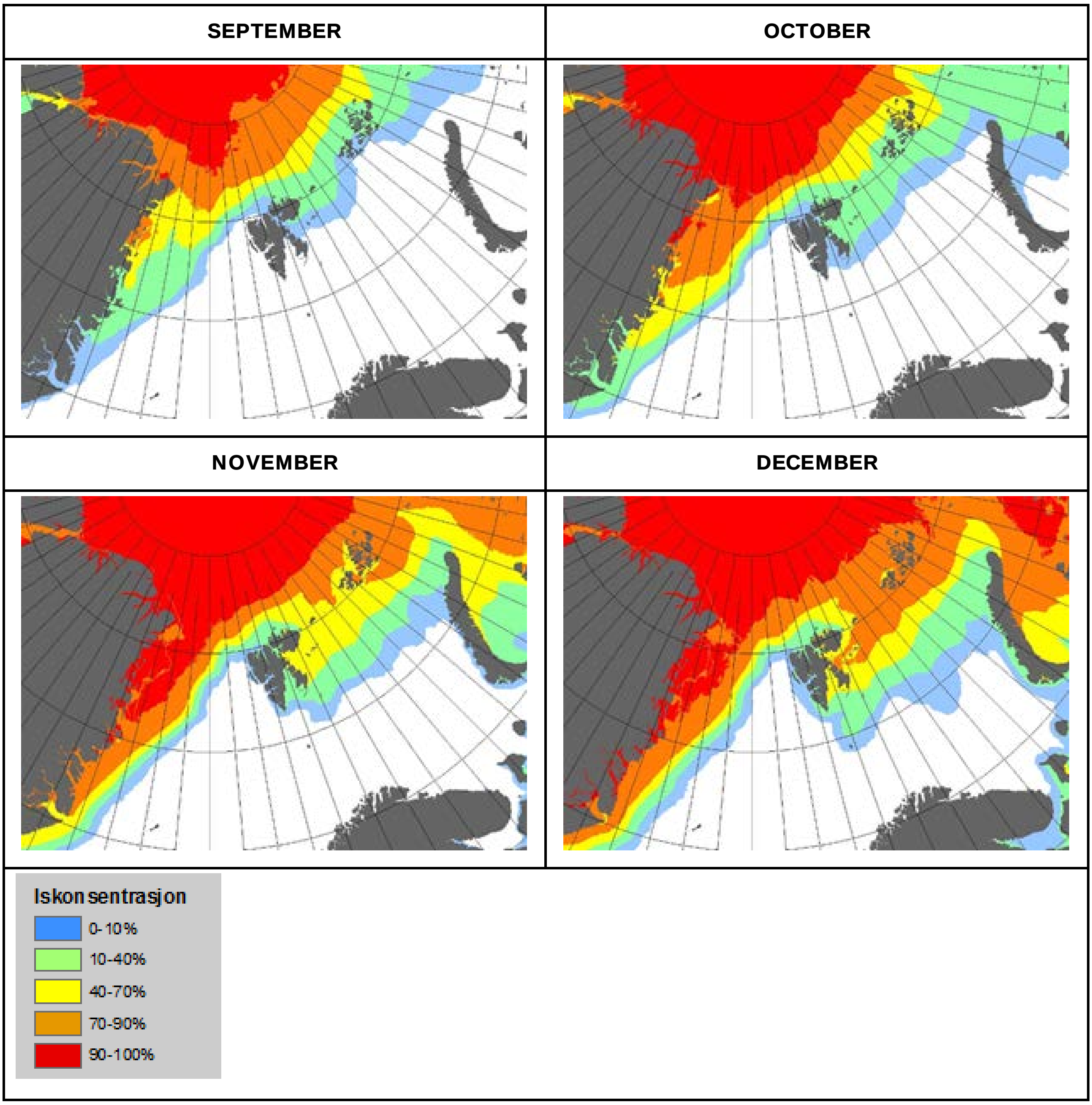


Figure C - 3 *Maps illustrating monthly (May-August) mean ice concentrations for the period 2001-2011 (MI, 2012).*



SEPTEMBER

OCTOBER

NOVEMBER

DECEMBER

Figure C - 4 *Maps illustrating monthly (September-December) mean ice concentrations for the period 2001-2011 (MI, 2012).*

Bjørnøya Island

Bjørnøya is the southernmost island of the Svalbard archipelago, situated approximately 235 km south-southeast of Spitsbergen and 400 km north-northwest of Ingøya at mainland Norway.

Bjørnøya is situated in the frontal zone of two major water masses; the warm Atlantic water and the cold water of polar origin. The North Atlantic current carries warm water to Svalbard, resulting in a climate much warmer than that of other regions at similar latitudes. The winters at Bjørnøya are therefore relatively mild; average temperature at the island is approximately -8 °C in the coldest month (January).

The northern part of the Bjørnøya forms a lowland plain about 30-100 meters high, with numerous shallow freshwater lakes. The coastline is bounded by vertical cliffs from 25 to 50 m high. Vegetation and fauna are limited. The only fauna found at the island is moss and some scurvy grass, no trees. Arctic fox (*Vulpes lagopus*) is the only land mammal that permanently inhabits the island.

One longer stretch of sandy beach (Kobbebukta) lies on the north coast (Weslawski, Zajaczkowski, Wiktor, & Szymelfenig, 1997), however the coast is mainly steep with high cliffs. Due to destructive powers of both waves and the tidal currents the coastal hills are eroded and caves are formed. The roofs of the caves usually fall in, and the detached pillars of rock appear, which is a characteristic feature along the coastline (Arctic Pilot, 2004). The south and southeast parts of the Bjørnøya are mainly mountainous.

From late December to late March Bjørnøya is usually surrounded by sea ice. However in extreme cases of very low temperatures and the island can be partially surrounded by ice as early as late October and as late as early May. Sometimes small icebergs are found in the vicinity of Bjørnøya, usually between May and October (Arctic Pilot, 2004).

Hopen Island

Hopen is an island in the south-eastern part of the Svalbard archipelago, preserved as a natural reserve. The island is identified as an Important Bird Area (IBA) by BirdLife international (BirdLife International, 2014), as it supports breeding colonies of black-legged kittiwakes (40 000 pairs), thick-billed guillemots (150 000 individuals) and black guillemots (1000 pairs). The island is surrounded by ice during most parts of the winter. The island is frequently visited by polar bears and arctic foxes.

Seabirds

The two main factors that determine the general geographic distribution of seabirds are the location of colonies (the breeding season) and the distribution of nutrients (G.H. Systad & Bustnes, 1999).

Typical seabirds, such as fulmars, gannets, cormorants, auks in addition to a number of gulls and some duck species, spend most of their time at sea. Other species such as grebes, diver ducks and some gulls are only intermittently depending on the sea. This may be in connection with moulting and wintering (NINA, 2008).

For the pelagic species, the prevalence of nutrients is largely controlled by oceanographic conditions such as front areas, currents, temperatures, salinity and extent of the ice edge, creating different habitat types preferred by different seabird species. Within their preferred habitat seabirds often occur in large flocks; several thousand individuals may occur within relatively small geographic areas. However, such high concentrations of seabirds are often very unstable, which means that the spatial distribution of seabirds on a small scale changes over time (Fauchald, Tveraa, Bårdsen, & Langeland, 2005).

The distribution pattern for pelagic seabirds can be divided into two phases (G.H. Systad & Bustnes, 1999):

- The migration period with regular migration between hatching areas and wintering/ moulting areas. The degree of regularity varies between the species.
- The overwintering period, the birds stay more or less stationary in a larger area with rich food availability. Migration will occur within this area depending on change in nutrition/diet.

The Barents Sea area is a globally important seabird region. In the summer 20 million individuals may be present in the area (Føyn et al., 2002). Several colonies of nesting seabirds are found here. Overview of the largest colonies along the Norwegian coastline is given in Figure C - 5.

The largest seabird colonies along the mainland coast of the Barents Sea are Sør-Fugløy, Nord-Fugløy, Loppa, Hjelmsøya, Gjesvær, Omgang, Syltefjord and Hornøya. All these spots are typical bird cliffs where pelagic feeding species dominates. Puffin is the most numerous species on the mainland with approximately 907 000 pairs in the Barents Sea; Kittiwake (37 000 pairs), Common Guillemot (14 000) and Herring gull (11 500 pairs) follows on the list (Seapop, 2014). Estimates of the nesting population of Common Guillemot indicates a very strong population in many of the colonies connected to the Barents Sea; the most numerous being Bjørnøya at estimated to 140 000 pairs (pers. med. K.E. Erikstad, 2015). Other numerous species are e.g. Great black-backed gull, Cormorant and Arctic tern.

The main source of data describing seabird's presence and migration patterns in Norway is the NINA Seabird Database and the Norwegian Polar Institute Seabird Database that are presented through the Seapop-program (www.seapop.no). The datasets is divided in coastal data based on counts from land, sea and air, and open ocean data based on boat transects outside the baseline. These two data sets are analysed separately in the ERA.

The seabird data are divided into three different datasets; one at Bjørnøya Island from Seapop (Seapop, 2011), one coastal dataset for the mainland Norwegian (Seapop, 2012) and one representing pelagic seabirds at the open sea (Seapop, 2013). The data sets are handled separately. It is important to note that pelagic and coastal seabirds can belong to the same population, but that the analysis is based on two different datasets after the seabirds' whereabouts in the different parts of the year.

In addition NINA has developed an additional dataset for pelagic Common guillemot for the autumn and winter; based on tracking devices (gls-loggers). The data has been collected since 2011, and birds originating from four different colonies are tracked; Bjørnøya, Hornøya, Hjelmsøya and Sklinna (see Figure C - 6).

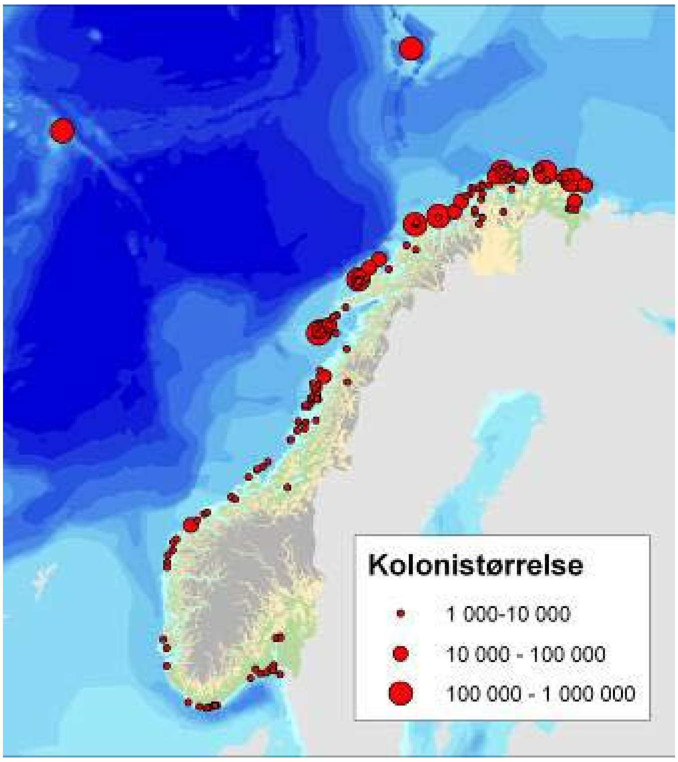


Figure C - 5 *Large seabird colonies along the Norwegian coastline, Bjørnøya and Jan Mayen (DN & HI, 2007).*

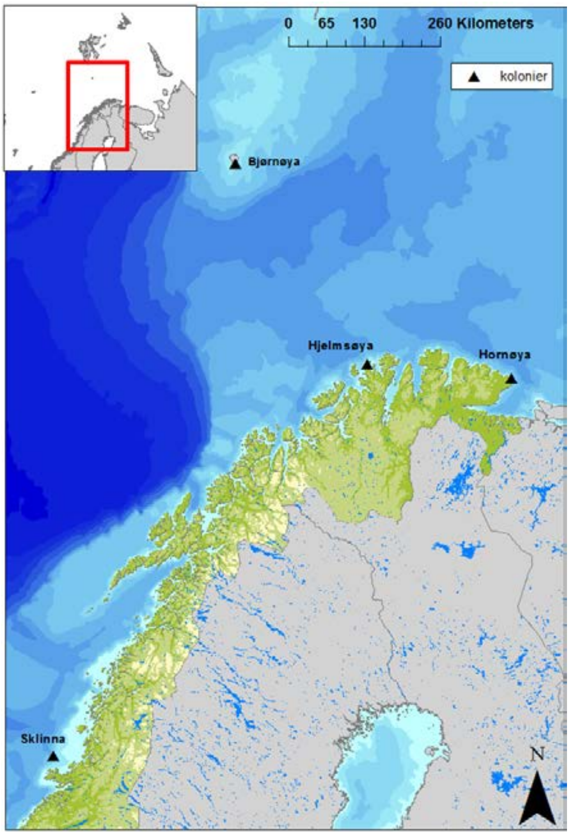


Figure C - 6 *Colonies included in the gls-logger study (NINA v/Kjell E. Erikstad, 2015).*

Overall vulnerability of seabirds to oil

As the habitat of seabirds to large extend is water an offshore/ near shore oil spill can potentially result in exposure to oil. Seabirds are vulnerable both to direct and indirect effects of oil exposure. The oil makes the feathers stick together so that the insulating function is reduced, and seawater reach the skin of the birds causing a risk of freezing to death. Even relatively small amounts of oil in the feathers may be crucial, because the water resistant effect in the feathers is deteriorated. Hence a spot of oil covering only 5 % of the bird's body may be fatal. The vulnerability is species dependent. Pelagic species experience more effective loss of heat (e.g. Auks) will be more vulnerable compared to e.g. Gulls, Swans, Geese and Ducks since they usually find sufficient nutrients on shore and are less exposed to heat loss.

The secondary effect is poisoning when oil enters the digestive system while they clean their feathers. The effects of poisoning happen gradually, and it varies whether or not it may be the primary cause of death. However, effects of poisoning may be one of the long-term effects seen long after the acute spill has come to an end (e.g. for individuals that survive oil pollution by moving towards and seek nutrients at shore).

The individual vulnerability to oil pollution for a seabird varies with a number of conditions other conditions; e.g. physical condition and fledging ability, and also presence, behaviour and use of the area within the affected area (T. Anker-Nilssen, 1987). Table C-8-1 gives a simplified presentation of the different seabird group's vulnerability to oil in the different seasons.

It is referred to (Brude et al., 2003), (Christensen-Dalsgaard et al., 2008), (Moe et al, 1993), (Peterson, 2001), (Piatt, Lensink, Butler, Kendziorek, & Nysewander, 1990) for more information.

Table C-8-1 *Simplified presentation of the different seabird groups vulnerability for oil in different seasons (T. Anker-Nilssen, 1994).*

Ecological group of seabirds	Summer area for				Autumn area	Winter area
	Nesting	**Search for food**	**Resting**	**Moulting**		
Pelagic diving	High	High	High	High	High	High
Pelagic surface feeders	Low	Average	Low	-	Average	Average
Coastal diving	High	High	High	High	High	High
Coastal surface feeders	Average	Low	Low	Average	Low	Low

Restitution time is the period a seabird population uses to build up to the same level as the population had before the acute population loss following an accidental oil spill. Generally the typical seabird species are characterized by late sexual maturity and low reproductive capacity, corresponding with a *minor* or *moderate* restitution capability (Table C-8-2).

Table C-8-2 *Characteristics for seabird populations. Ability for restitution is estimated from the different species life history parameters (primary fecundity and survival). Trends for the populations are evaluated based on results from the national monitoring program for seabirds (e.g. (Lorentsen & Christensen-Dalsgaard, 2009). Red list status in in accordance to (Kålas, Viken, Henriksen, & Skjelseth, 2010), and is divided into categories; CR = Critically endangered. EN = Endangered. VU =Vulnerable and NT = Near Threatened.*

Species	Ecological group	Ability for restitution	Trend of the population. mainland	Status in Norway	Individual vulnerability (ERA)
Fulmar	PSF	Small	Negative		2
Cormorant	CD	Large	Positive	Specie of responsibility[1]	3
Shag	CD	Large	Stable	Specie of responsibility[1]	3
Common eider	CD	Average	Stable		3
Steller's eider	CD	Small	Negative	VU[2]	3
Great Black-backed gull	CSF	Average	Stable	Specie of responsibility[1]	1;Sept.-March/ 2;April-Aug.
Herring gull	CSF	Average	Stable	Specie of responsibility[1]	1;Sept.-March/ 2;April-Aug.
Kittiwake	PSF	Average	Negative	VU[2]	2
Brünnich's Guillemot	PD	Small	Negative	NT[2]	3
Common Guillemot	PD	Small	Negative	CR[2]	4
Puffin	PD	Small	Negative	VU[2]	3

1) *A species is defined as Norwegian specie of responsibility when the Norwegian population is ≥ 25% of the European population.*

2) *Red list status for the Norwegian mainland.*

Core areas

Identified particularly vulnerable areas with respect to the seabird species listed in the Norwegian Red List are defined as *core areas* for these species (Fauchald, 2011), (G.H. Systad & Strøm, 2012). A *core area* is defined as the smallest area where 75% of all individuals within the study area was modelled to be. This information is central to understanding how birds interact with other ecosystem components and will be important to evaluate the environmental impacts of oil spills. The Barents Sea is for instance core area for both Puffin and Brünnich's Guillemot in the autumn, as well as other species and periods (Figure C - 7). Recent data from the Norwegian Polar Institute (Steen, Lorentzen, & Strøm, 2013) has shown that the Barents Sea region is a very important area for Common Guillemot in the winter.

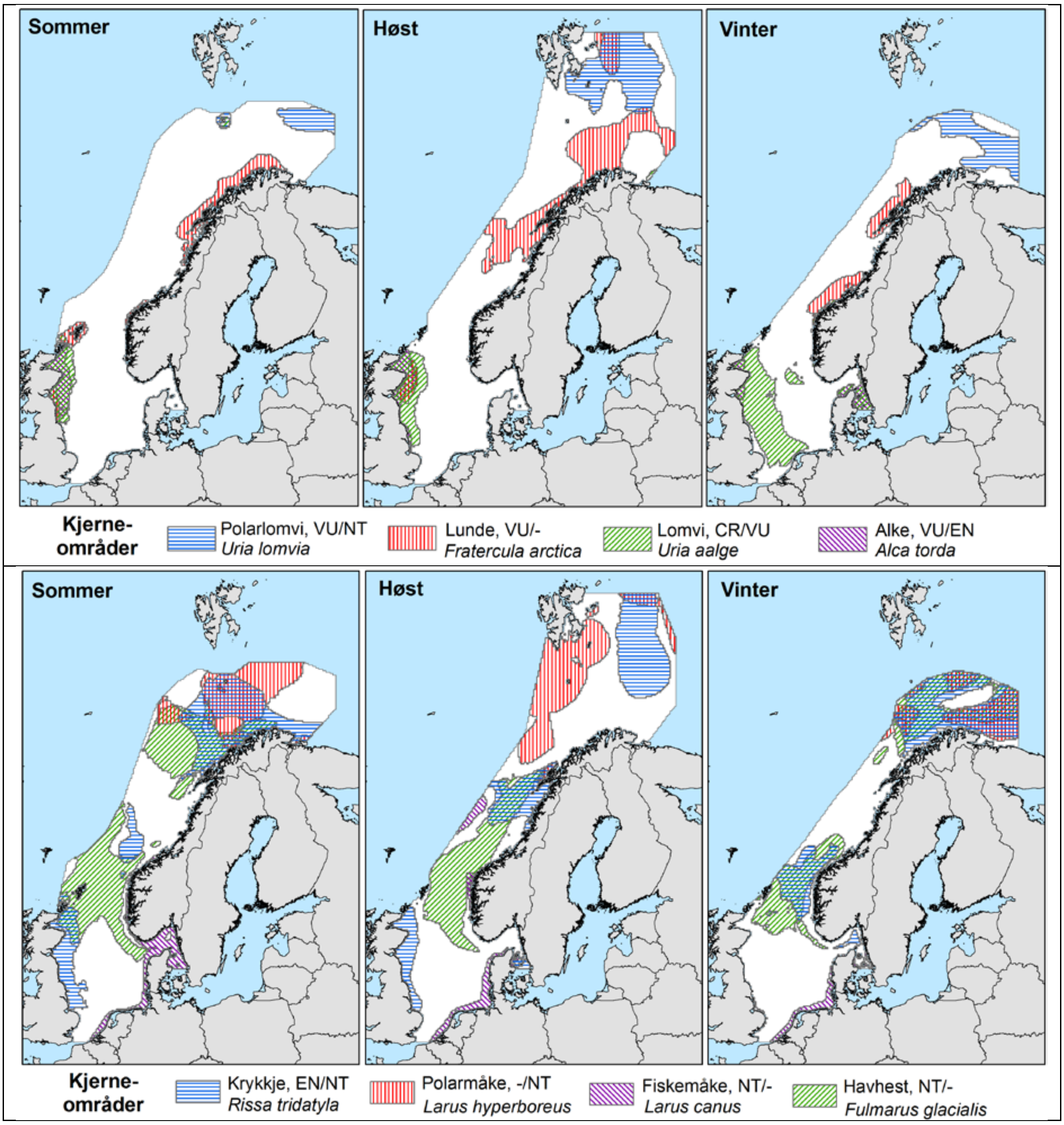


Figure C - 7 *The core areas of auks and pelagic surface-feeding seabirds listed in the Norwegian Red List (Fauchald, 2011). In this figure: sommer = summer, høst = autumn, vinter = winter. See Table 5-1 for species translation.*

Pelagic seabirds

Seapop-data

Data describing the pelagic species at the open sea is collected using the standard method of line transects. The birds are counted from 8-10 m above the sea surface under a constant speed of approximately 20 km/h. All birds seen within a sector of 300 m straight and 90 ° to one side of the boat are counted. Easily detectable species that tend to follow the boat (e.g. gulls and fulmars) is probably overestimated, while smaller, rarer and diving species (e.g. little auks) are underestimated. The data collected is further used to estimate the general distribution of birds (estimated number of birds per 10 km^2) using models such as the Generalized Additive Models (GAM) (Seapop, 2015a). The data are converted into shares of the total estimate for the different sea areas. Pelagic seabird data includes records from the North Sea, Norwegian Sea and Barents Sea. Data from the North Sea are mainly from the ESAS (European Seabirds At Sea) database, while data from the Norwegian Sea and the Barents Sea mainly comes from the SEAPOP database (seapop.no). The data are analysed separately for the three different sea areas and for three distinct seasons: winter (November 1 to March 31), summer (April 1 to July 31) and autumn (August 1 to October 31). Data coverage is shown in Figure C - 8.

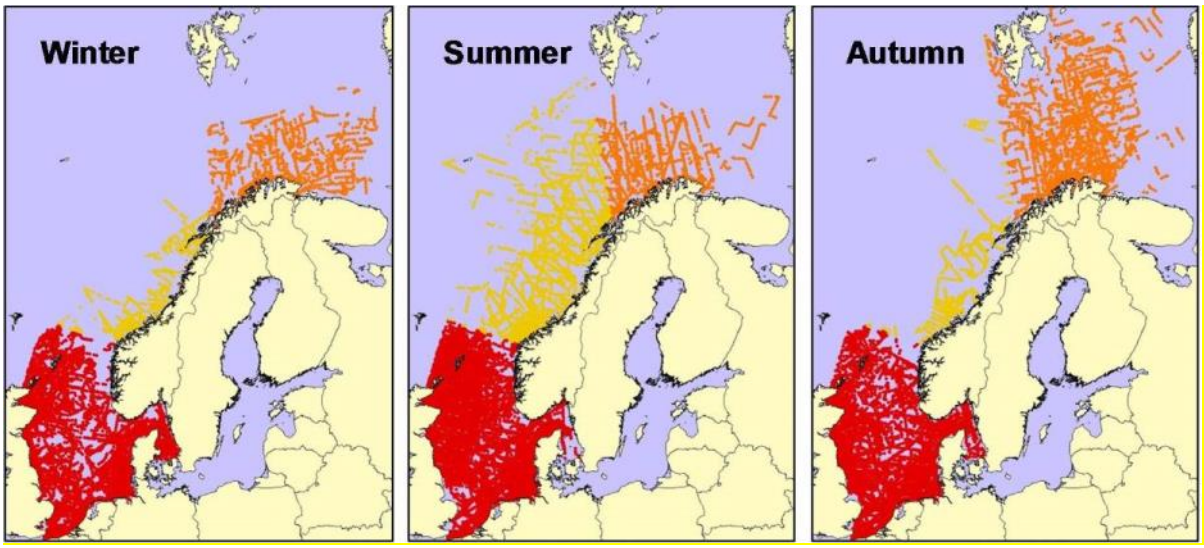


Figure C - 8 *Data Coverage in the open sea. Each point represents an aggregated 20 km line. Different colours show different sea regions, from south to north: the North Sea, Norwegian Sea and Barents Sea. Data for the North Sea and the Norwegian Sea is used in this work (SEAPOP / Per Fauchald, 2011).*

For the Barents Sea, the open ocean data includes the pelagic diving species razorbills, little auks, guillemots, puffins, arctic petrels and polar guillemots. The pelagic surface-feeding species includes fulmars, gannets and kittiwakes and the coasts surface-feeding species includes herring gull, glaucous gulls and great black-backed gulls. The distribution of the populations from the database are presented below (Seapop, 2013).

<table>
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<tr><th>Spring</th><th>Autumn</th><th>Winter</th></tr>
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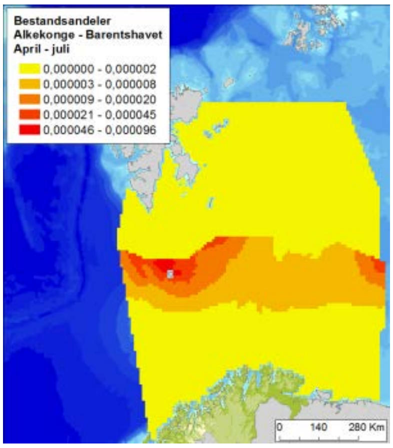
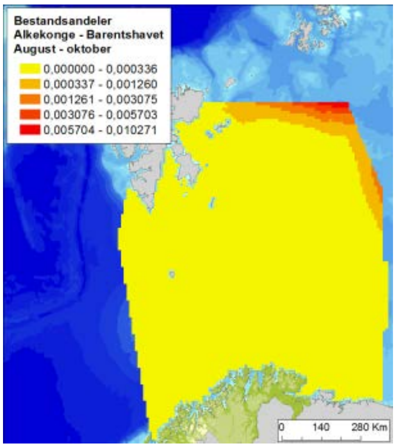
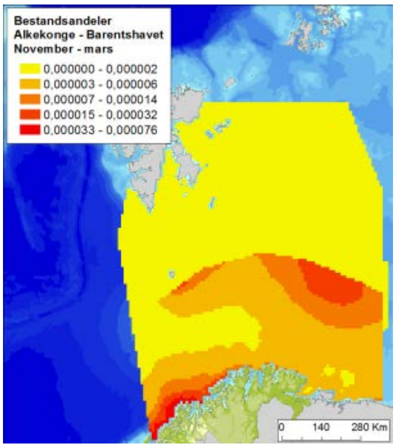
<td> </td>
<td> </td>
<td> </td>
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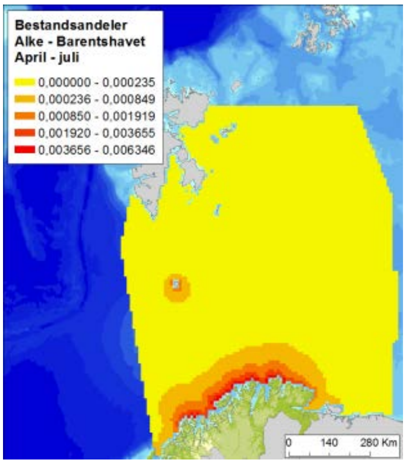
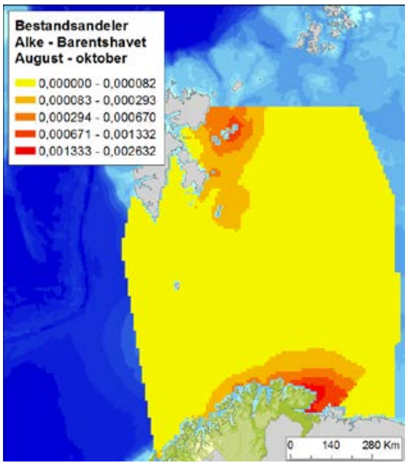
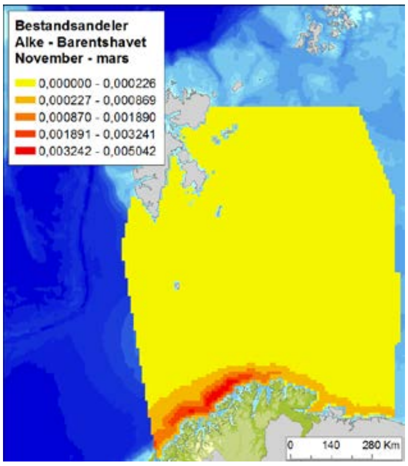
<td> </td>
<td> </td>
<td> </td>
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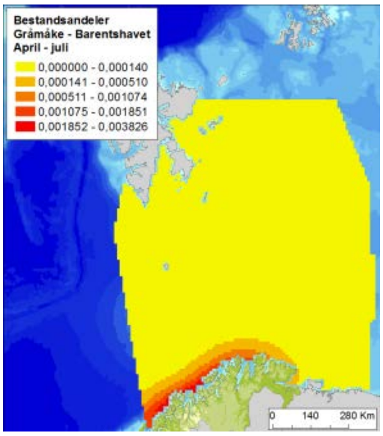
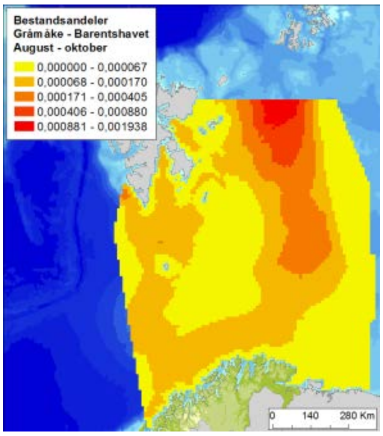
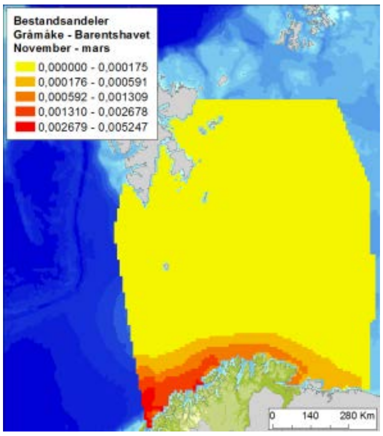
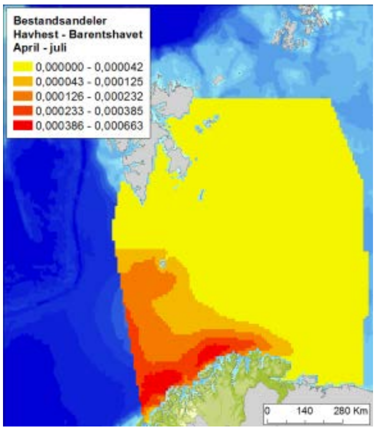
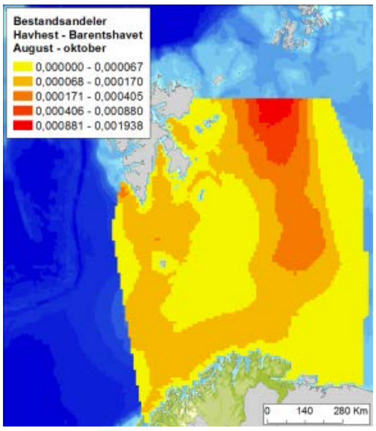
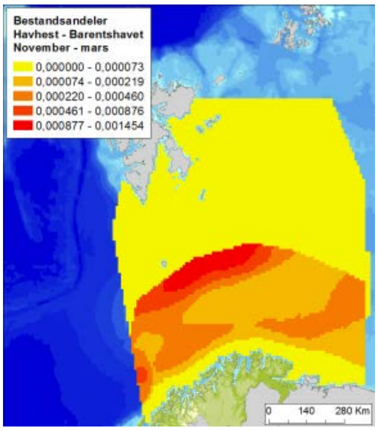
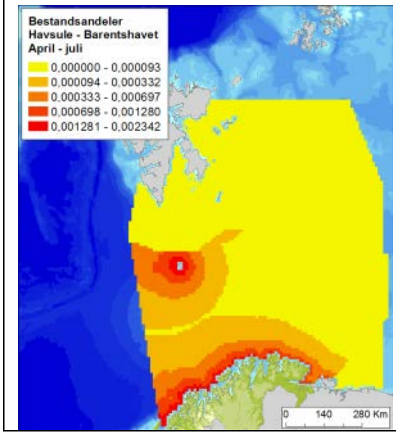
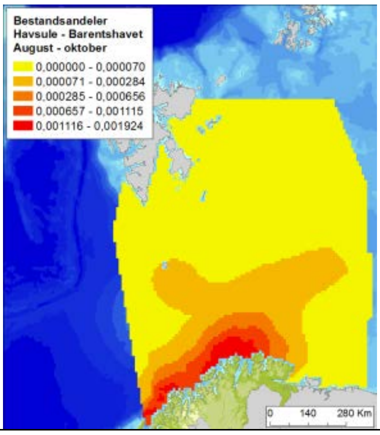
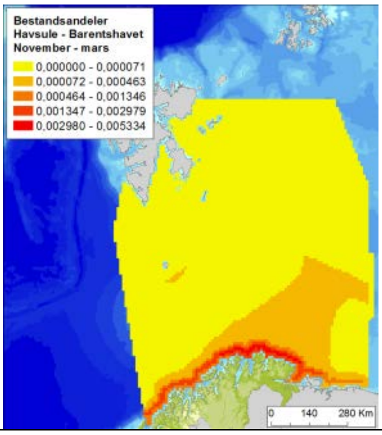
Herring Gull (gråmåke)

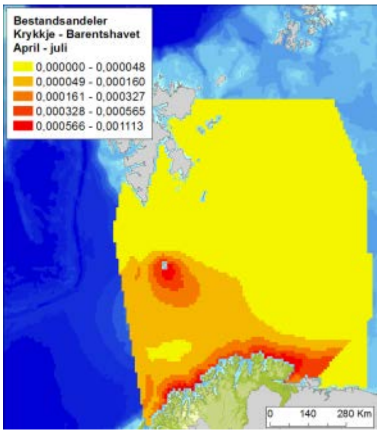
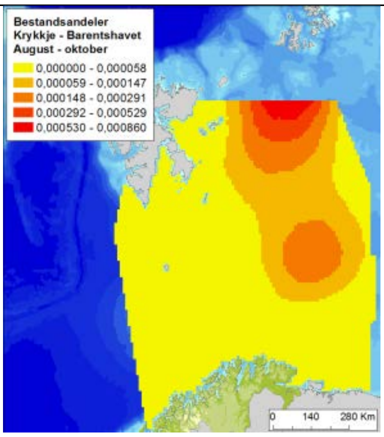
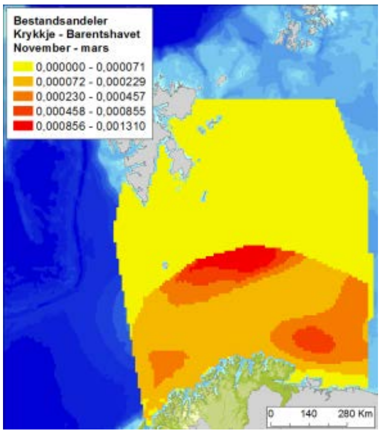
Spring	Autumn	Winter
		

Arctic Petrel (havhest)

Spring	Autumn	Winter
		

Northern Gannet (havsule)

Spring	Autumn	Winter
		

Kittiwake (krykkje)		
Spring	**Autumn**	**Winter**
		

Common Guillemot (lomvi)		
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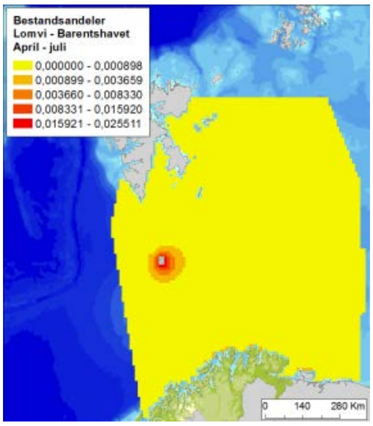
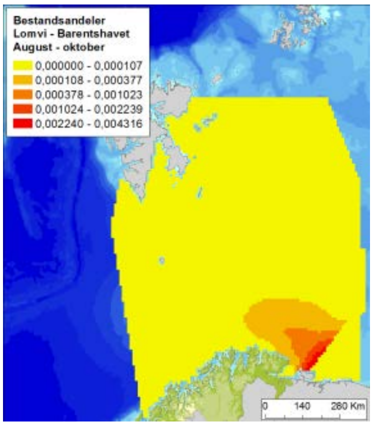
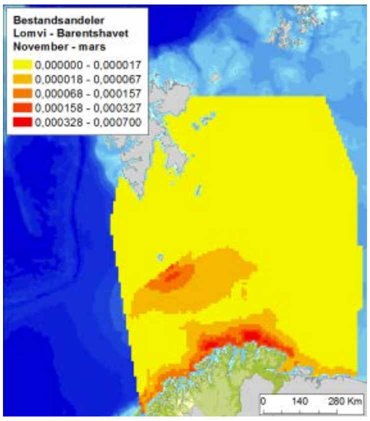
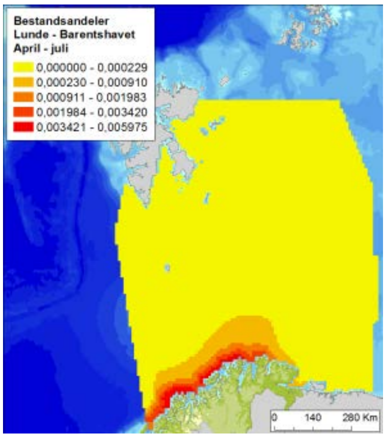
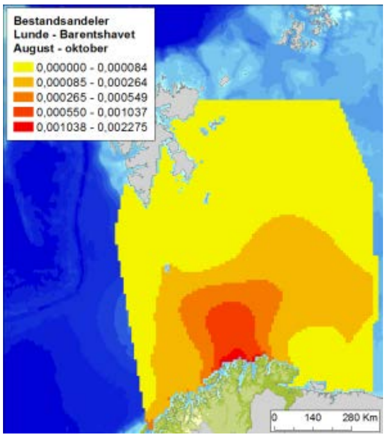
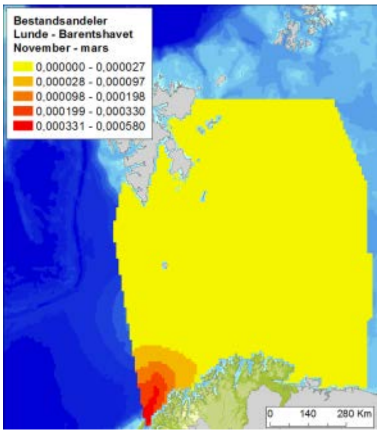
		

Puffin (lunde)		
Spring	**Autumn**	**Winter**
		

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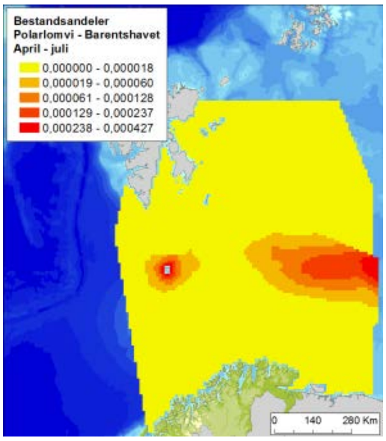
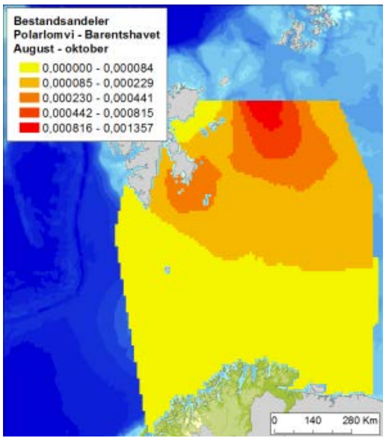
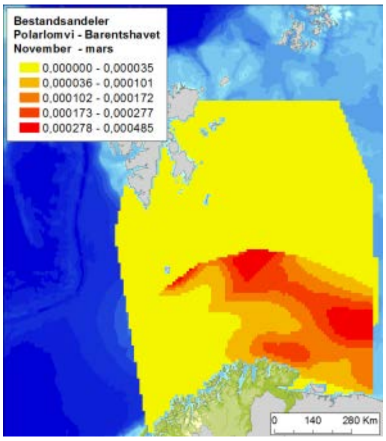
<td> </td>
<td> </td>
<td> </td>
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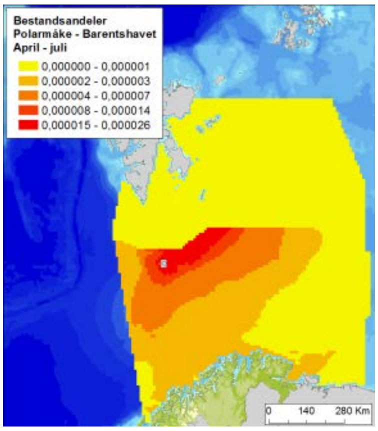
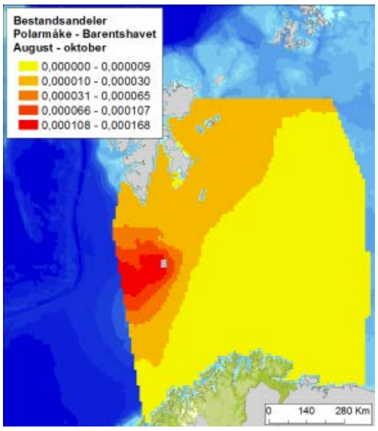
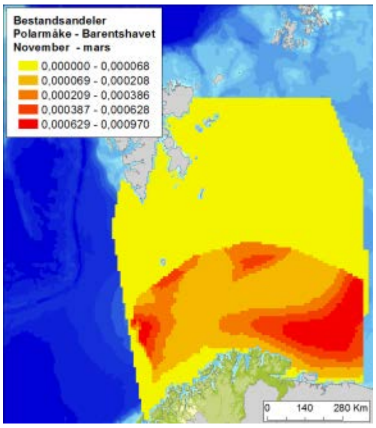
<td> </td>
<td> </td>
<td> </td>
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<table>
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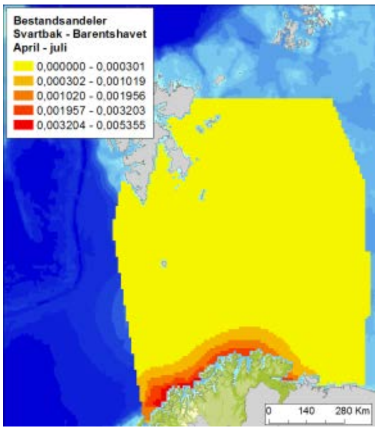
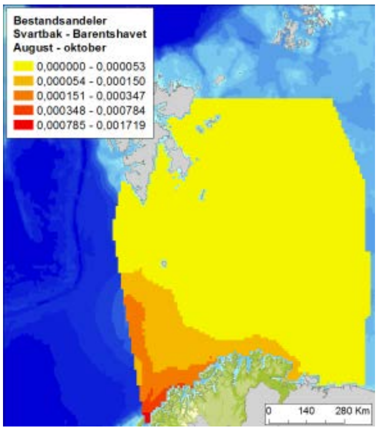
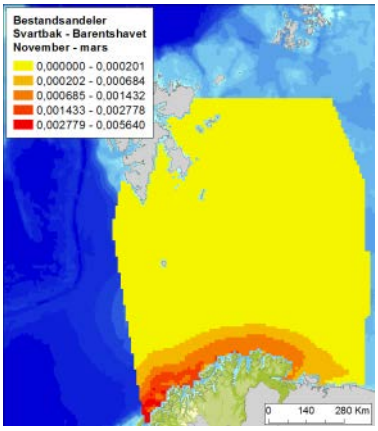
<td> </td>
<td> </td>
<td> </td>
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Gls-data for Common Guillemot

The gls-datasets are developed by NINA through the Seapop-program, based on tracking data from about 300 marked Common guillemots originating from four different colonies; Sklinna, Hjelmsøya, Hornøya and Bjørnøya. The data has been collected since 2011. The project is part of the Seapop/SEATRACK (seabird tracking)-project which is running from 2014-2018.

A colony consists of adult, breeding seabirds during autumn and winter: The colonies are of variable size;

- Sklinna ca. 700 par
- Hjelmsøya ca. 12 000 par
- Hornøya ca. 11 000 par
- Bjørnøya ca. 140 000 par

The combined dataset, including all colonies, are primarily determined by the Bjørnøya-colony, as this is considerably larger than the rest. More than 90 % of the Norwegian breeding population of Common guillemot is assumed to be disitributed among the defined colonies.

The population breeding at Sklinna appears primarily in the Barents Sea in autumn before flying southward for the winter period. The different datasets are illustrated in Figure C - 9 to Figure C - 11.

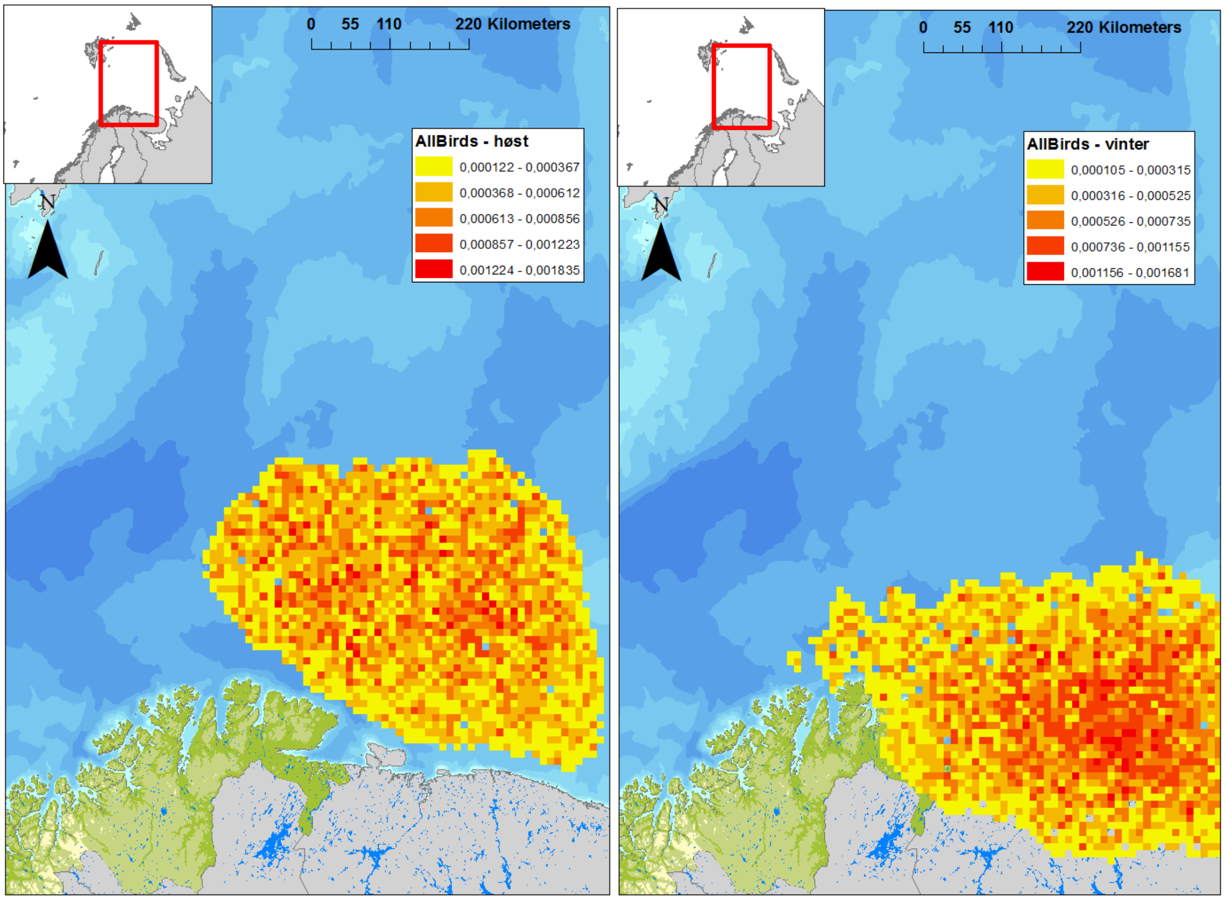


Figure C - 9 *Datasets for Common guillemot in the autumn (to the left) and winter (to the right) seasons, based on gls-logger data combined from tracked birds from colonies Bjørnøya, Hjelmsøya, Hornøya and Sklinna.*

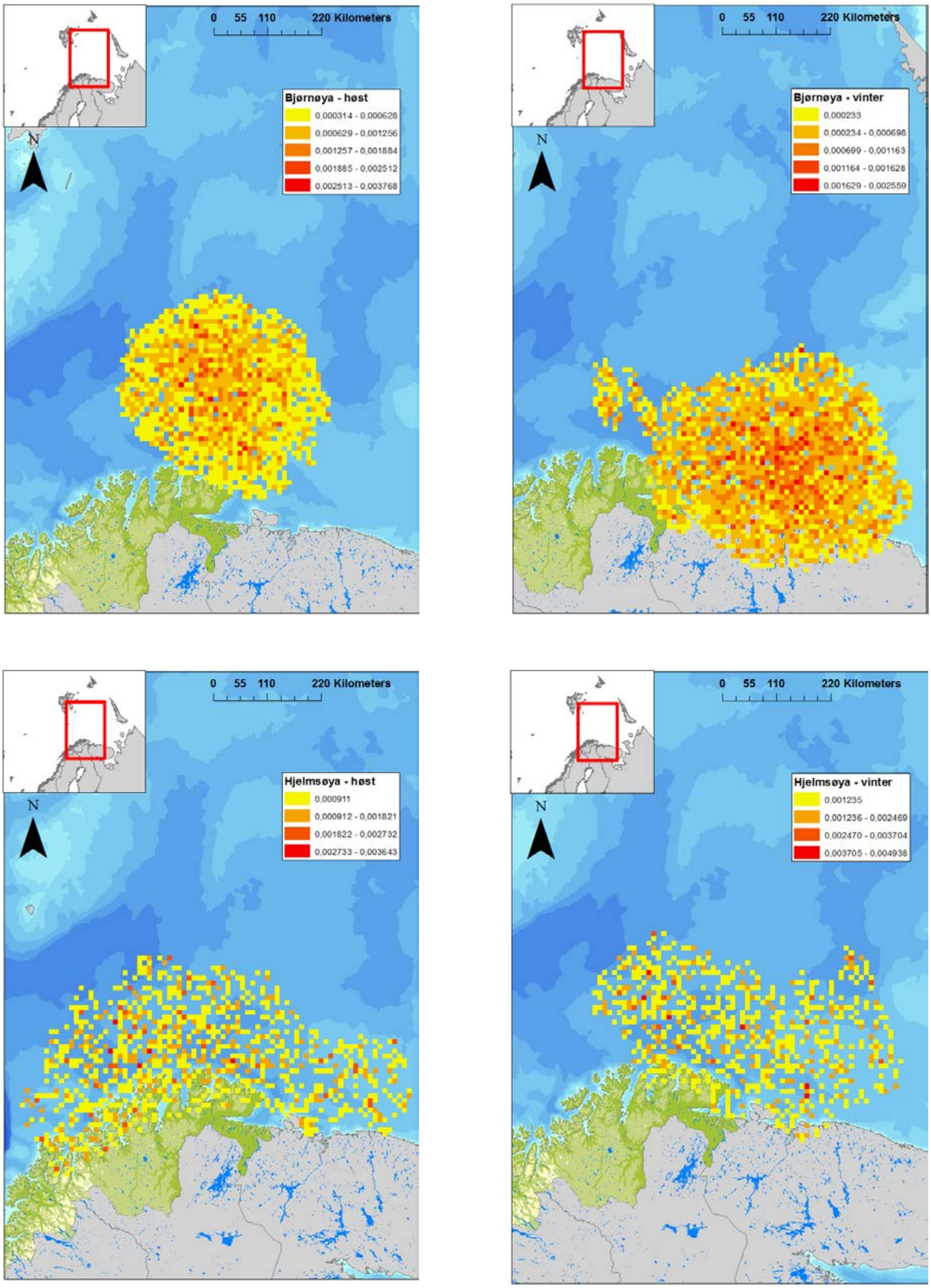
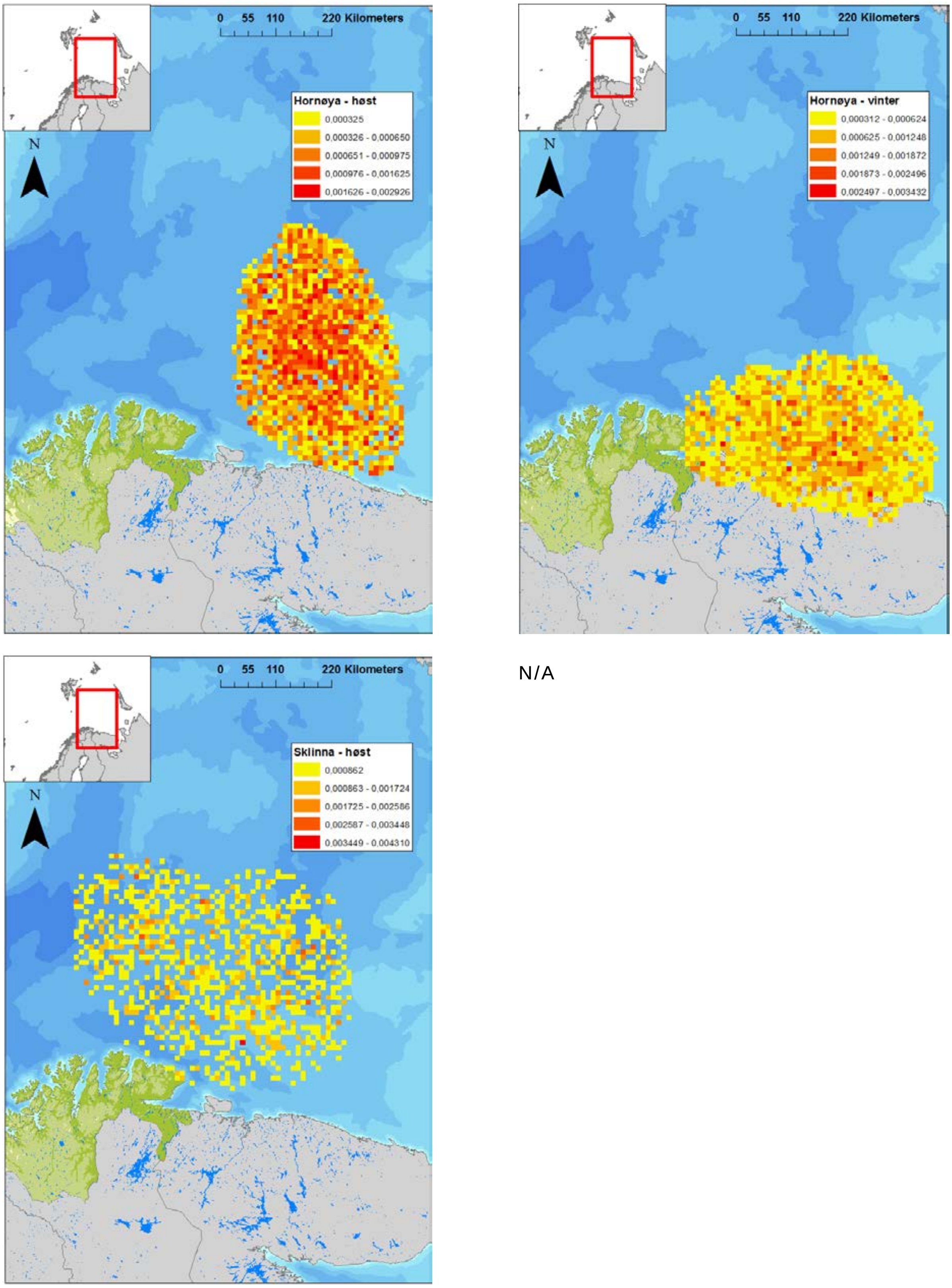


Figure C - 10 *Datasets for Common guillemot in the autumn (to the left) and winter (to the right) seasons, based on gls-logger data from tracked birds from colonies Bjørnøya (upper figures) and Hjelmsøya (lower figures).*



N/A

Figure C - 11 *Datasets for Common guillemot in the autumn (to the left) and winter (to the right) seasons, based on gls-logger data from tracked birds from colonies Hornøya (upper figures) and Sklinna (lower figures). NB! Common guillemot breeding at Sklinna is not present in the Barents Sea in the winter season; i.e. not relevant as dataset.*

Ivory gull

The Ivory gull (*Pagophila eburnea*) represents a VEC connected to the ice zone. The species is of particular interest as it is associated with sea ice all year, no existing VEC datasets exist and because new knowledge about the species distribution outside of breeding season became available.

The ivory gull is one of few sympagic (ice associated) birds in northern hemisphere. It is also a poorly known seabird species and probably one of the most threatened birds due to bio magnification of contaminants and the ongoing and forecasted reduction of its main habitat, the sea ice. It is a medium-sized gull with white plumage and black legs and eyes (Figure C - 12). At sea it is a surface feeder that by hovering and contact dipping in open leads in ice filled waters, forage primarily on small fish, such as arctic cod *Boreogadus saida*, and macro-zooplankton, such as amphipods and euphausiids. Ivory gulls are also scavengers of marine mammals remain

The Ivory gull has a patchy circumpolar breeding distribution across the high arctic. Scattered colonies occur in arctic Canada, Greenland, Svalbard, Franz Josef Land, on islands in the Kara Sea and on Severnaya Zemlya. The entire population is estimated to 14000 breeding couples. 80% is breeding in the Russian Arctic and only a small number (100-200 pairs) is hatching at Svalbard. In Svalbard the Ivory gull breeds on the eastern part of Spitsbergen (as far south as Hornsund), Barentsøya, Kong Karls Land and Nordaustlandet, with the highest colony densities occurring in the east and north. The species breed as single pairs or in colonies, rarely containing more than 10-50 pairs. Breeding sites at Svalbard is indicated in Figure C - 12.

Figure C - 12 *Picture of an ivory gull (left) and map of breeding sites at Svalbard (right). (Source: npolar.no)*

Ivory gulls leave the colonies soon after the young have fledged in late August and beginning of September. The post-breeding movement of the north Greenland, Svalbard and Franz Josef land has been studied using satellite transmitters (Gilg et al., 2010). The study show that the birds move up to the MIZ between Svalbard and Severnaya Zemlya in the northwestern Laptev Sea (Russia) and stay in this area until mid-October when they start migrating southwest along the ice to the wintering areas in southeast Greenland Figure C - 13. The spring migration starts in March and the MIZ in the Barents Sea is an important foraging area for the entire Barents Sea population (including Russian birds) from March until May (pers comm Halvard Strøm). Important pre-breeding foarging areas along the MIZ in the Barents Sea is illustrated in Figure C - 14 (Source: Hallvard Strøm). The birds disperse into the breeding areas in May and lay their eggs within the two first weeks of June.

An example of the datasets utilized in the dynamic modelling of environmental risk is illustrated in Figure C - 15. The figure shows the distribution of Ivory Gull in a belt of 20-50 % ice concentration in the marginal ice zone.

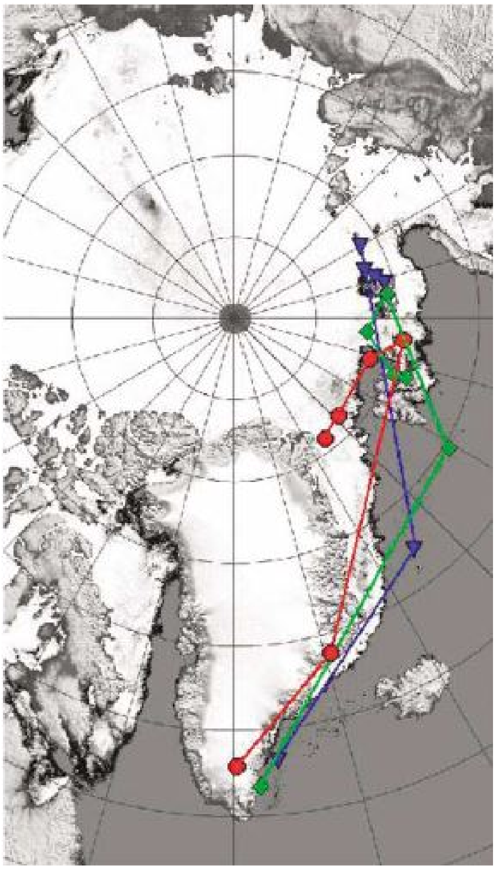


Figure C - 13 *Post breeding movements (July – December) of north Greenland (red) Svalbard (green) and Russian/Franz Josef Land (blue) populations.*

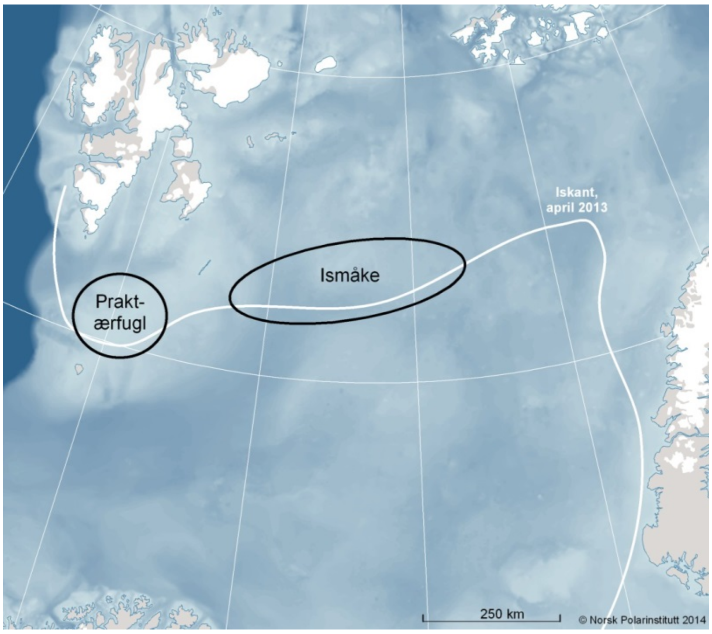


Figure C - 14 *Important pre-breeding foarging areas along the MIZ in the Barents Sea. (Source: Hallvard Srøm).*

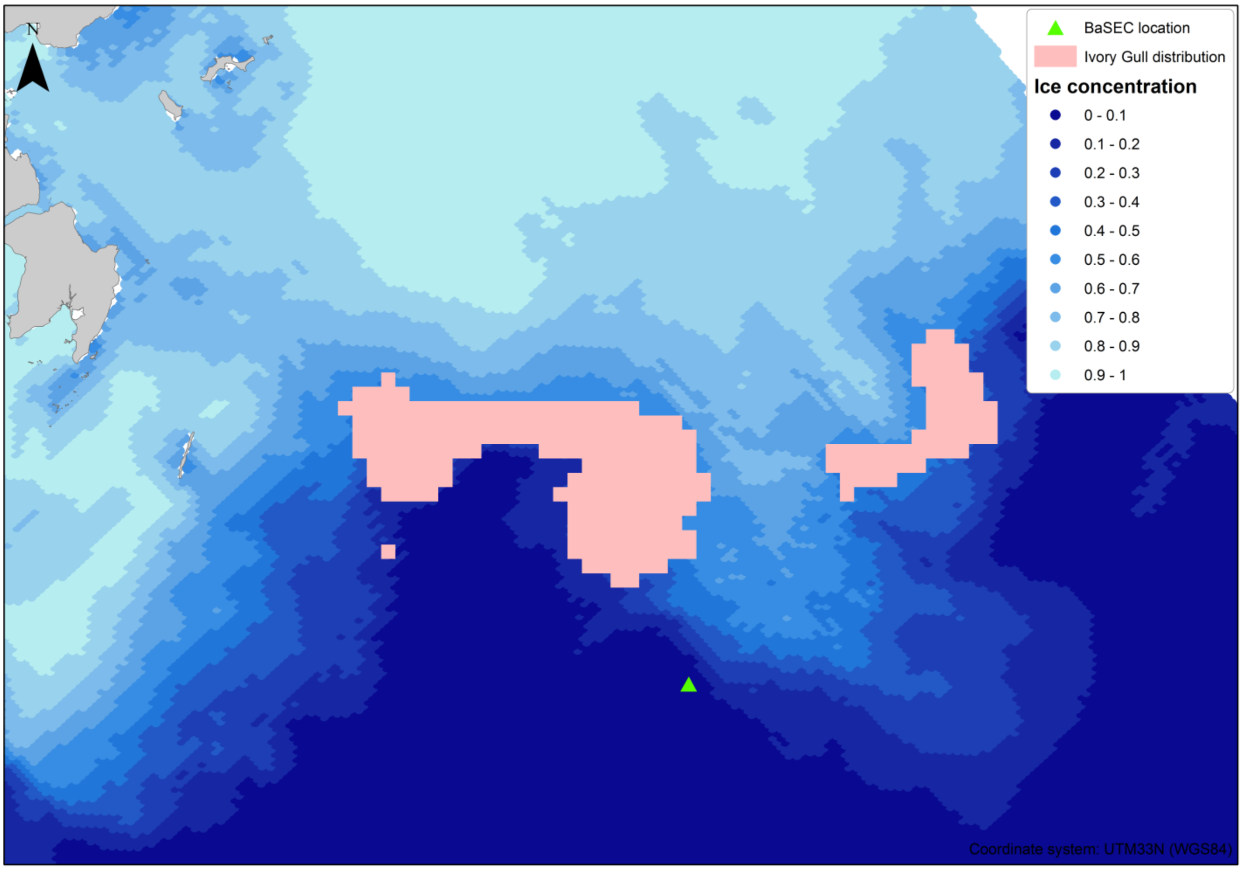


Figure C - 15 *One of the datasets utilized in the dynamic modelling of environmental risk for Ivory Gull.*

Coastal seabirds

Seabirds adjacent to coastal areas vary between species and seasons, depending on the behaviour and activity.

Species connected to the coastal areas are diving ducks (eider, scoter, velvet scoter), shags (cormorants and common shags), terns, some gulls and auks; the black guillemot. These species are mainly found in areas that can be seen from land, but may also move further out at sea, especially in shallow waters. In addition several of the pelagic species uses the coastal areas for nesting in the spring/summer.

The datasets used in damage based analyses of seabirds in coastal areas, are developed based on data from NINA’s national seabird database (Seapop, 2012). The datasets includes the following species:

Razor-billed Auk, Common Gull, Red-necked Grebe, Long-tailed Duck, Northern Fulmar, Northern Gannet, Great Northern Diver, Black-legged Kittiwake, Goosander, Common Guillemot, Atlantic Puffin, Brünnich’s Guillemot, Glaucous Gull, King Eider, Red-breasted Merganser, Velvet Scoter, Red-throated Diver, Steller’s Eider, Great Black Cormorant, Black Scoter, Great Black-backed Gull, Black Guillemot, European Shag and Common Eider.

The geographical distribution of the species is presented in Figure C - 16 – Figure C - 18.

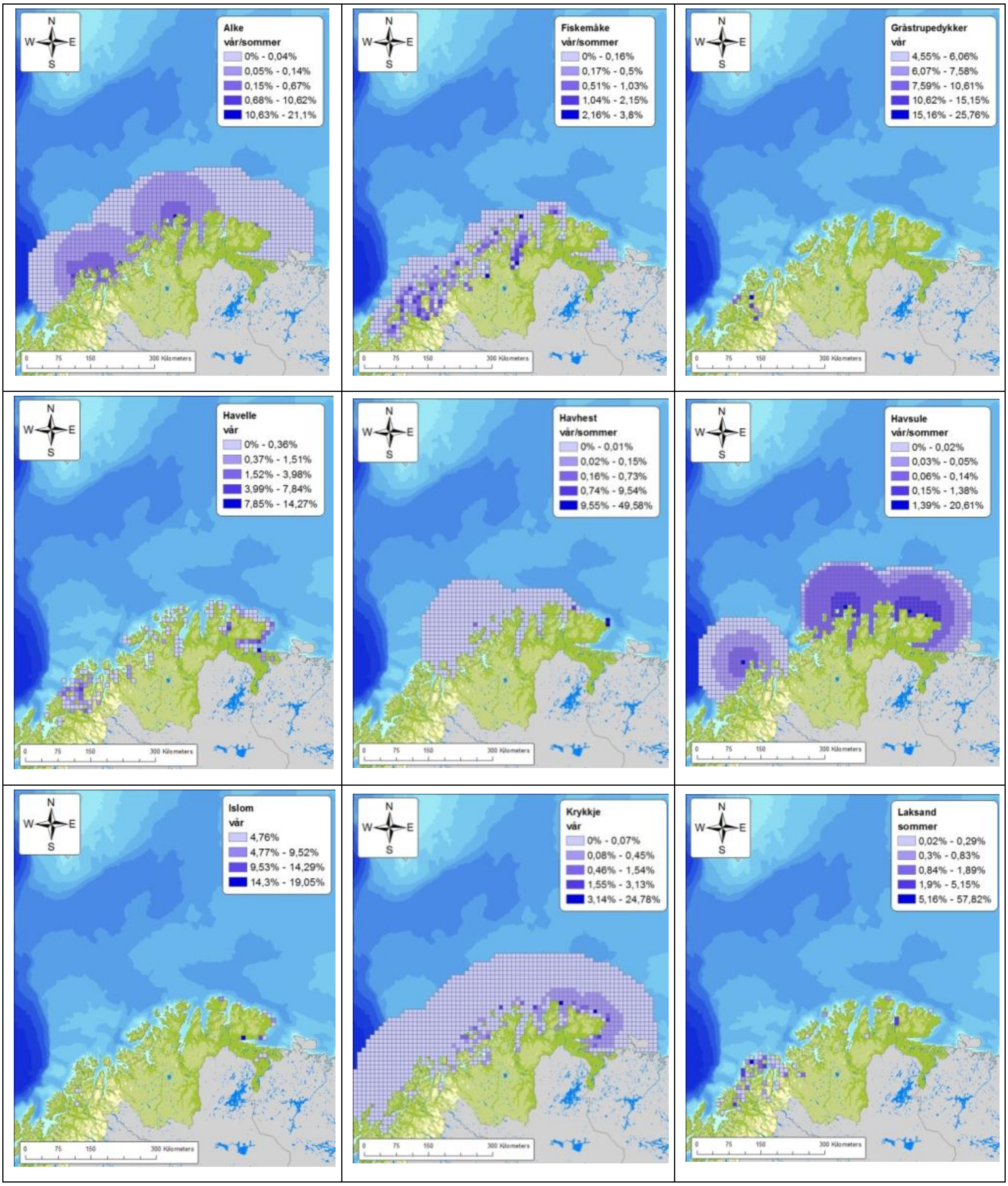


Figure C - 16 *Distribution of razor- billed auk, common gull, red-necked grebe, long-tailed duck, northern fulmar, northern gannet, great northern diver, black-legged kittwake and goosander (from top left corner to lower right corner) in the nesting period (Seapop, 2012).*

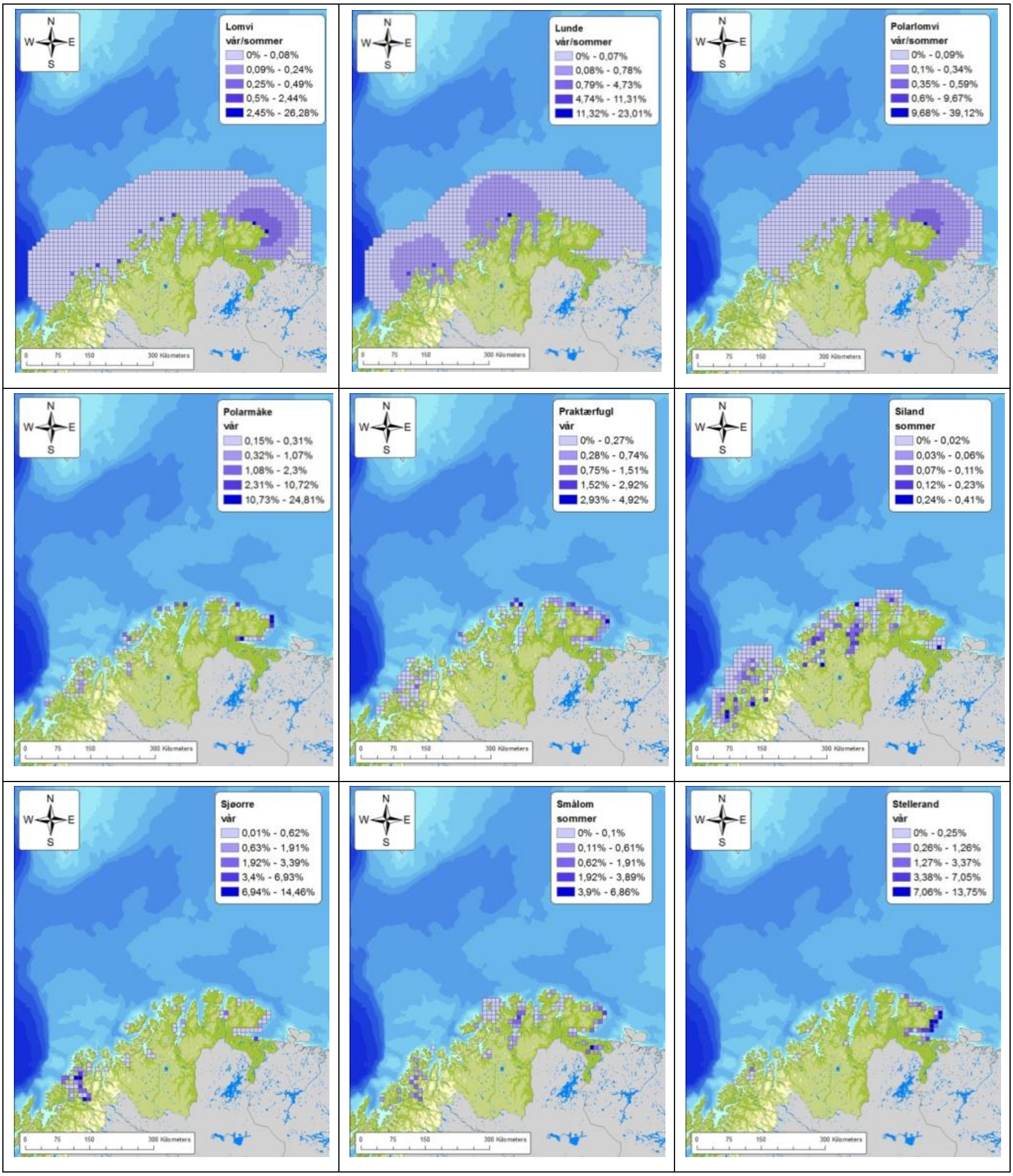


Figure C - 17 *Distribution of common guilemot, atlantic puffin, brünnich's guillemot, glaucous gull, king eider, red-breasted merganser, velvet scoter, red-throated diver and steller's eider (from top left corner to lower right corner) in the nesting period (Seapop, 2012).*

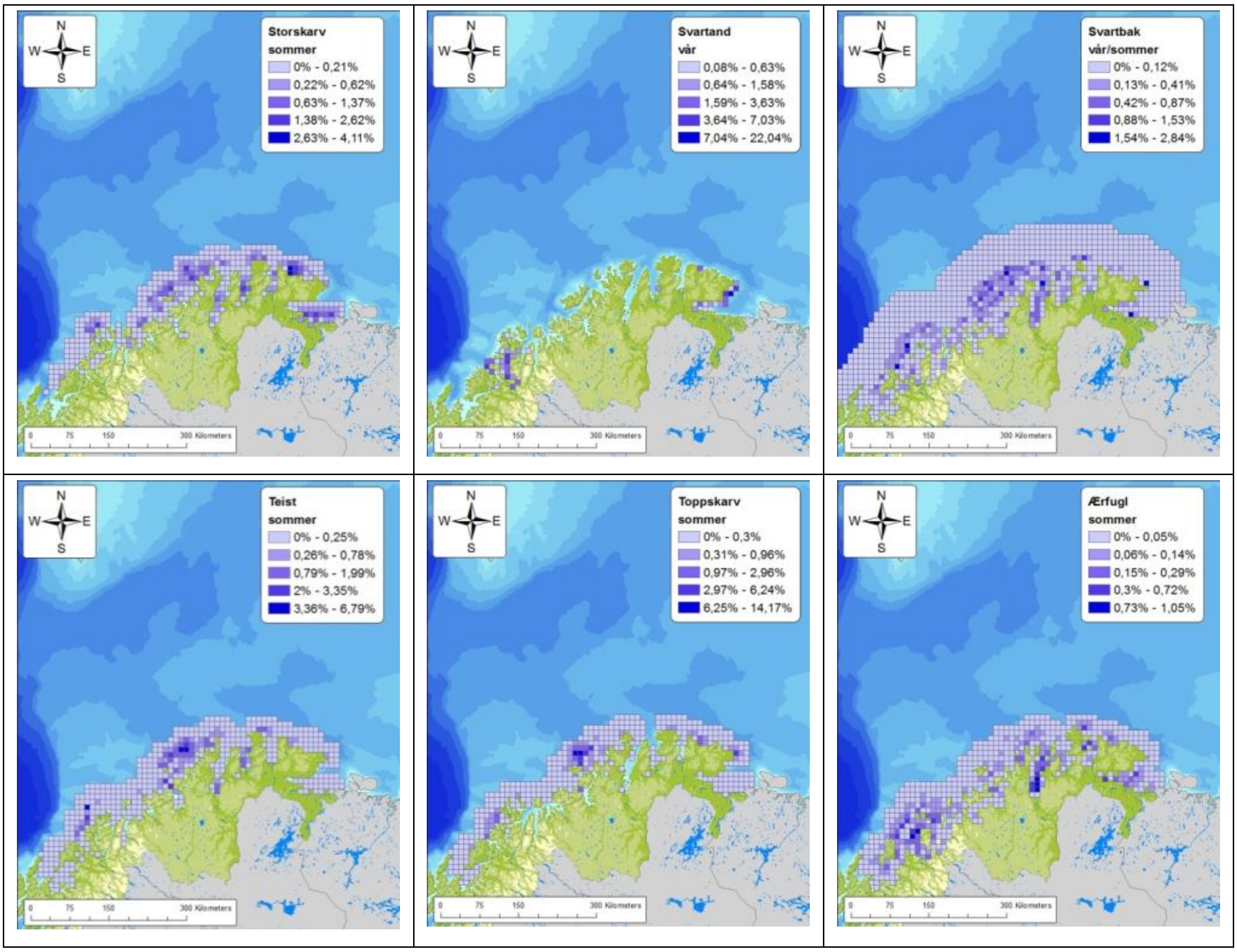


Figure C - 18 *Distribution of great black cormorant, black scoter, great black-backed gull, black guillemot, european shag and common eider (from top left corner to lower right corner) in the nesting period (Seapop. 2012).*

Coastal seabirds at Svalbard / Bjørnøya

Bjørnøya is known to support some of the largest seabird colonies in the Northern Atlantic area (Saksen & Bakken, 1985). The most common species of seabirds at Bjørnøya are: Common Guillemot, Brünnich's Guillemot, Little Auk, Black-legged Kittiwake, Northern Fulmar and Glaucous Gull (Norwegian Polar Institute, 2011). Bjørnøya is a home for the world's northernmost largest breeding colony of the Common Guillemots and one of the world's northernmost colonies of Razorbill. Counting data from 2006 indicated approximately 70 000 pairs of Common Guillemot; however more recent estimates are approximately 140 000 pairs (pers. medl. K.E. Erikstad, NINA). The island is also the eastern boundary for the Great Northern Driver (also known as The Common Loon).

The island of Bjørnøya is visited by birds that usually do not habitat in the northern parts of the world. It is due to the strong northern winds that transport them to the island. Overall 126 different seabird species were identified at Bjørnøya, however only 33 of them are found to be breeding at the island. Some of the breeding species are: Grey Phalarope, Arctic Skua, Great Skua, Great Black-Backed Gull, Arctic Tern, Black Guillemot, Razorbill, Atlantic Puffin and Long-tailed Duck (Norwegian Polar Institute, 2011).

During the seasonal migration the Pink-footed Geese, Barnacle geese and Brent geese that are usually habitat in Svalbard can be found in the Bjørnøya Island as well. Especially the whole population of Barnacle geese land on the Bjørnøya during autumn south-bound migration (Norwegian Polar Institute, 2011).

Based on counting data for seabirds at Svalbard and Bjørnøya distribution datasets has been generated (Seapop, 2011). The following species were adapted to the 10 × 10 km grid: Northern Fulmar, Arctic Petrel, Kittiwake, Common Guillemot, Brünnich's Guillemot, Little Auk, European herring gull, Great northern loon, King eider, Red-throated loon, Steller's Eider, Black guillemot, Common Eider and Glaucous Gull (Seapop, 2011). See Figure C - 24Figure C - 19 **-** Figure C - 21 for distribution of the most important populations.

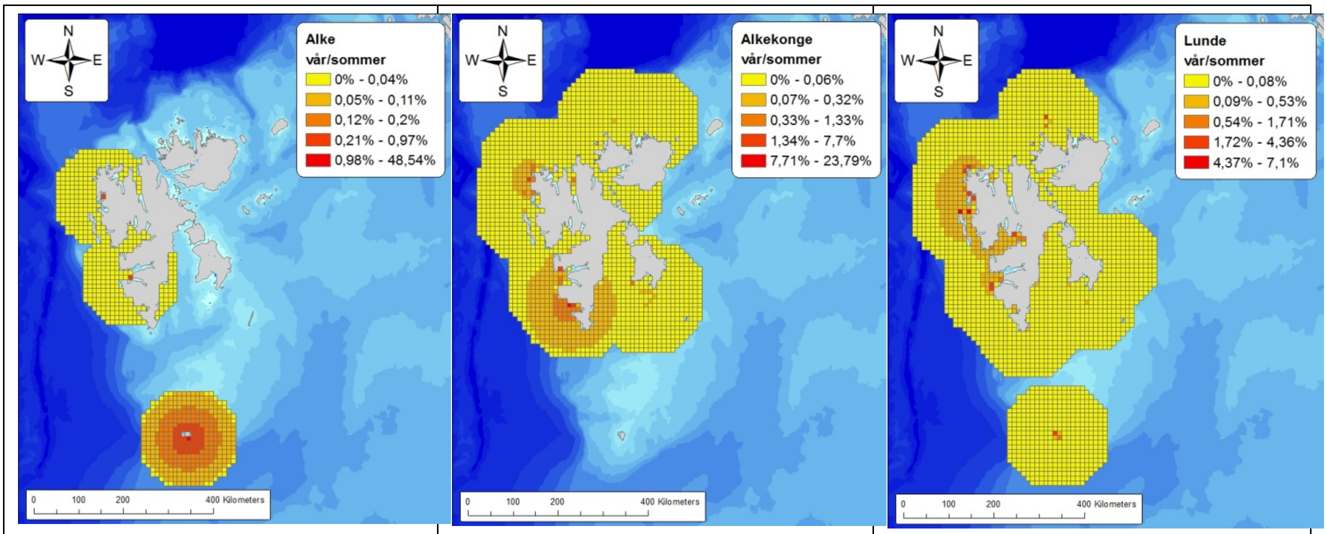


Figure C - 19 *Geographic distribution of razor-billed auk, little auk and Atlantic puffin (April-August) in the nesting period (Seapop, 2011).*

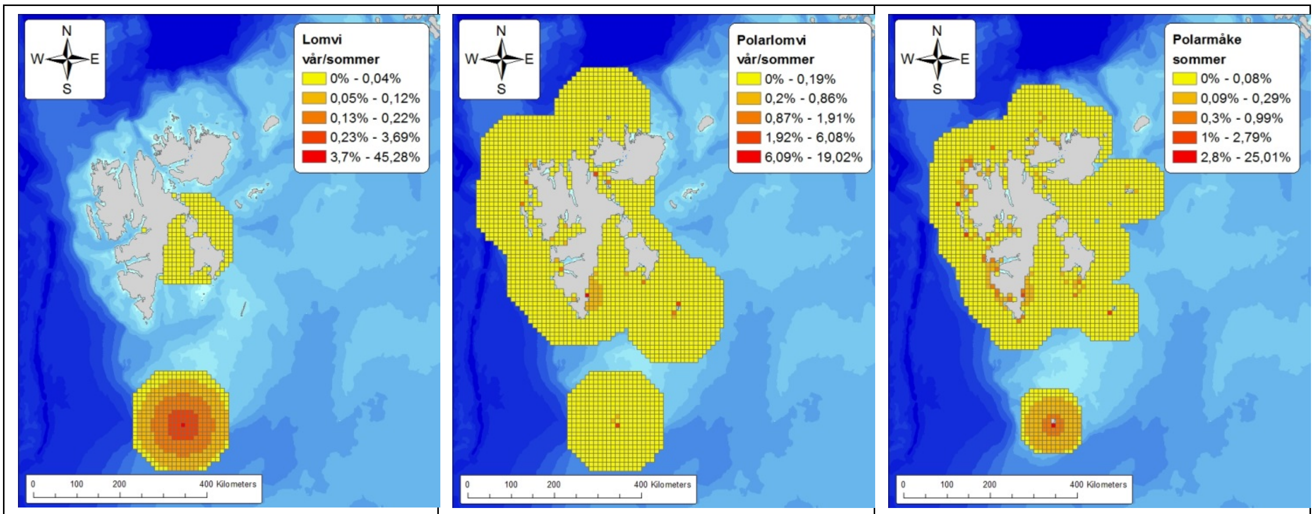


Figure C - 20 *Geographic distribution of common guillemot, Brünnich's Guillemot and Glaucous Gull in the nesting period (Seapop, 2011).*

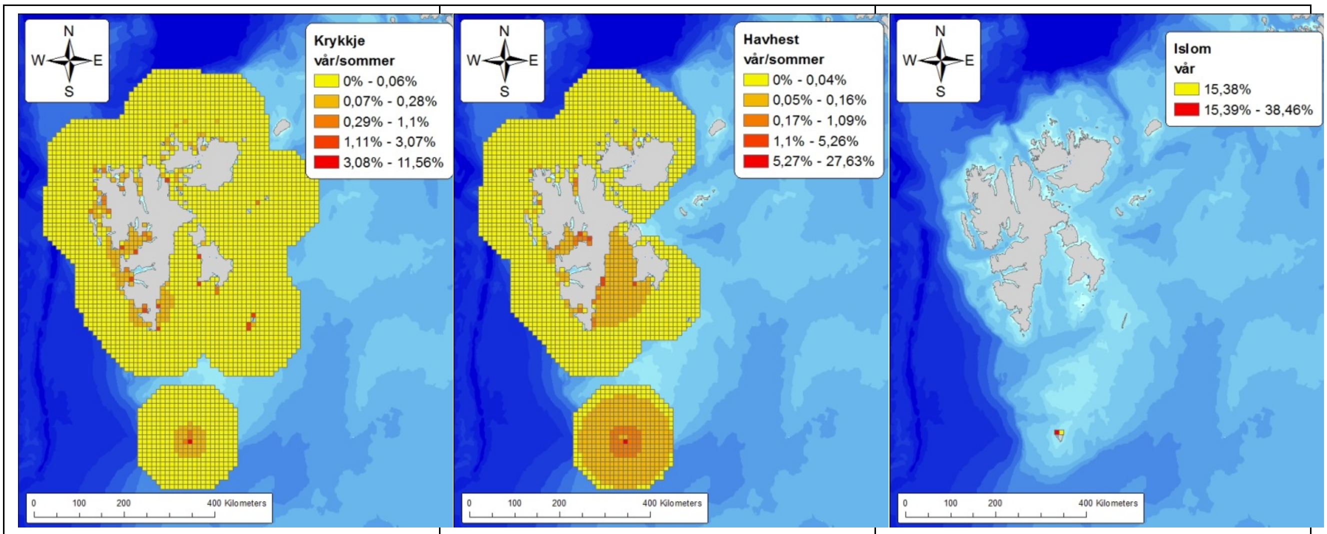


Figure C - 21 *Geographic distribution of black-legged kittiwake, Northern Fulmar and Great northern loon in the nesting period (Seapop, 2011).*

Marine mammals

The Barents Sea is an important habitat for marine mammals; the polar bear, walrus, six different species of seals and 17 whale species are found in the sea area. The primary sources of nutrition are benthic fauna and pelagic prey (Kovacs, Haug, & Lydersen, 2009). Some of the species stay in the sea area year round (i.e. ringed seal and bearded seal), while others are only present in the summer (i.e. common minke whale, humpback whale, fin whale). The quantitatively most important marine mammals in the Barents Sea are the polar bear, ringed seal, harp seal, bearded seal, walrus and common minke whale (Kovacs et al., 2009).

In addition there are a few marine mammals found along the Norwegian coastline of the Barents Sea; the grey seal, harbour seal and marine otter.

Seals and walrus

The harp seals are only found in the North-Atlantic and are divided into three different populations based on the reproductive areas. The largest population is found in the northwest Atlantic waters, and breeds at the drift ice by Newfoundland in Canada. One population is based in the Barents Sea, breeding at the drift ice in the White Sea (see Figure C - 22). In the Norwegian Sea the population of one year and older animals are gathered at the drift ice north of Jan Mayen to reproduce. They are often gathered in large flocks both along the ice edge and in open water. The Svalbard area and the north Barents Sea are both registered as foraging areas for the Norwegian Sea population (DN & HI, 2007).

The bearded seals are found widely distributed in the Barents Sea (see Figure C - 22); however in great numbers along the northern coast of Spitsbergen and Nordaustlandet, in the fjords on the west coast of Spitsbergen as well as in the drift ice in the Barents Sea. In the breeding and moulting period (May-June) the bearded seal is often found on small ice floes (Føyn et al., 2002).

The ringed seal is found in the ice covered parts of the Barents Sea and close to Svalbard, and is the most numerous species in these areas (Føyn et al., 2002).

The walrus is very numerous in the Svalbard area. The species prefers the drift ice areas, but has common haul-out area on land when the sea ice is gone (Figure C - 23). The walrus normally appear in smaller flocks. The distribution is partially determined by the distribution of sea ice (Føyn et al., 2002).

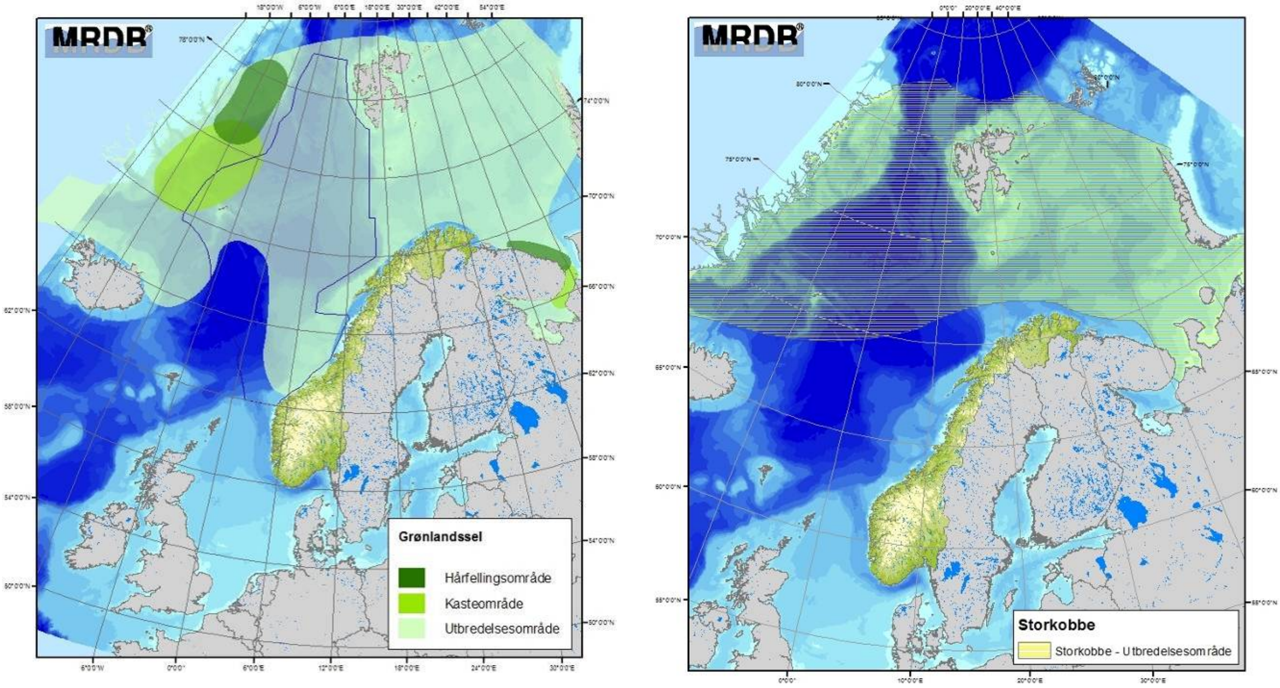


Figure C - 22 *Distribution of harp seal (left) and bearded seal (right) (DN & HI, 2007)*.

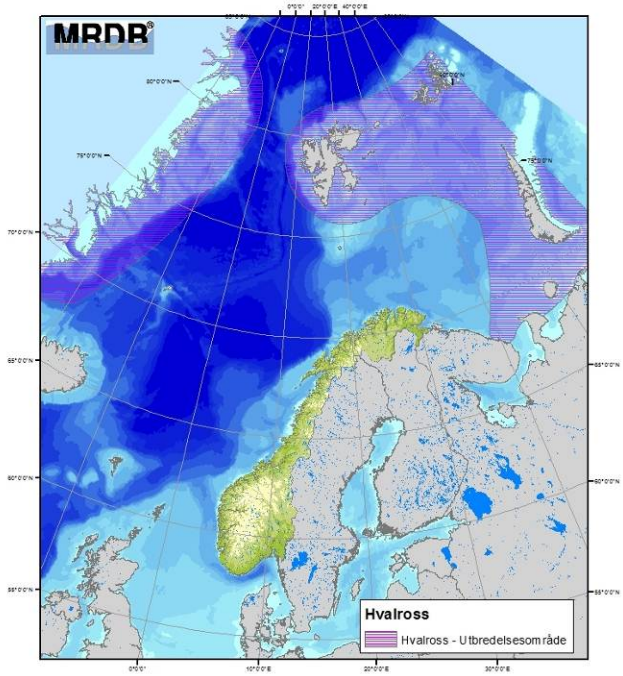


Figure C - 23 *Distribution of walrus (DN & HI, 2007).*

The Harbour seal *(Phoca vitulina)* are present in larger and smaller colonies along the Norwegian coast (Figure C - 24). The species is relatively locally based and reside near colonies year round (range of a few tens of km).

Counting data from the period 2011-2014 indicates a total population of about 7500 harbour seals along the Norwegian coast. This is an increase from the period 2003-2006, to a similar level as seen in 1996-1999. The highest concentrations are found in Nordland and Troms, with approximately 3500 individuals (Havforskningsinstituttet, 2015).

Harbour seals give birth in the last half of June and lactation period lasts three to four weeks. The young seals have lost their neonatal coat at birth and can go in the water after only a few hours. However, they are extremely sensitive to disturbances at that time, and until they have developed strong swimming skills (DN & HI, 2010). For harbour seals, moulting occurs in August-September.

Bjørge (Bjørge, 2008) propose the following appropriate population classifications based on biological principles; Skagerrak population (from Østfold to Vest-Agder), western populations (from Rogaland to Troms / Lopphavet), Finnmark population (from Lopphavet the Russian border), and the Svalbard population (at Prins Karls Forland). The three largest distributions of seals are in Nordland (2 874). south Trøndelag (1 750) and in Møre and Romsdal (1 447) (A. Bjørge, Øien, & Fagerheim, 2007).

In the Norwegian Red List (2010), harbour seals are classified as *vulnerable* (VU) (Norwegian Biodiversity Information Centre, 2010).

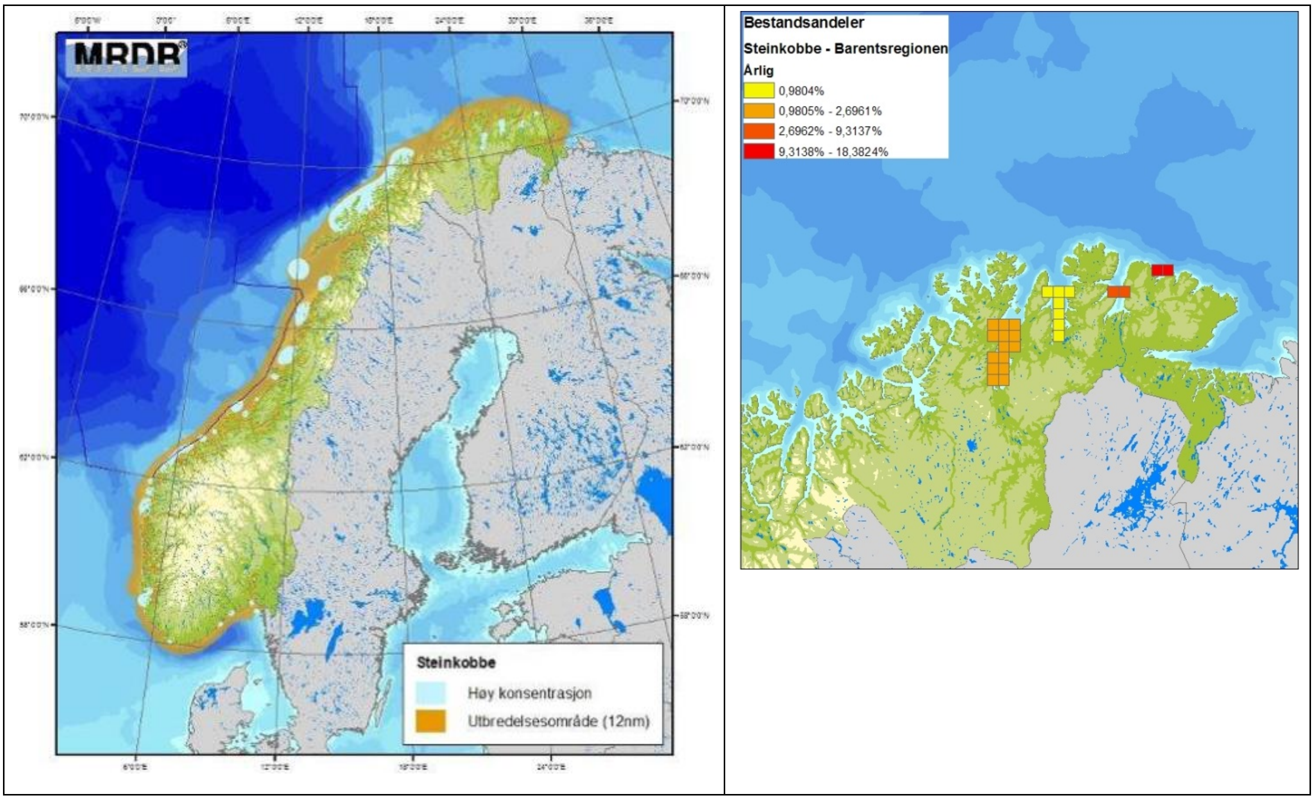


Figure C - 24 *Distribution of harbour seals in Norwegian waters (MRDB, 2010); (DN & HI, 2010). Legend for the left hand map, from top to bottom: high concentration and distribution range (12nm). Right hand map: annual average population distribution.*

Grey Seal (*Halichoreus grypus*) are found in colonies along the Norwegian coast from Rogaland to Finnmark. Outside the breeding season, the population is spread along the coast for foraging, and the prevalence of multiple colonies can overlap (Figure C - 25). During the moulting and breeding season, grey seals gather in large colonies (Føyn et al., 2002); (Bjørge, 2008).

About 1 200 grey seals are born every year along the Norwegian coast, mainly in Trøndelag and northwards. The number of cobs is estimated through systematic counting in all breeding colonies along the Norwegian coast. The Institute of Marine Research has developed a population-model based on all counting data and registered hunting from the period 1979-2010. The model indicates a total population of 8700 individuals in 2011, which is an increase from 3000-4000 seals estimated in 1960-70. However, counting of cobs in the area Froan-Vega in September-October 2014 indicated a considerable reduction in the number of cobs, approximately 40 % less than in 2007. There are indications that bi-catch in net-fishing may be one of the main reasons for the reduction (Havforskningsinstituttet, 2015).

South of Stadt the only breeding locality known for grey seals is at the Kjør archipelago in Rogaland, where up to 40 young seals have been counted during the breeding season. However, tagging experiments and other observations have shown that grey seals from the British Islands, where there is a large population of them (around 100 000 individuals), spend large parts of the North Sea to feeding and therefore may contribute to many of the grey seal sightings off southern Norway (DN & HI, 2010).

Bjørge (Bjørge, 2008) proposed to divide the Norwegian distribution of grey seals in three populations: one population south of Stad, one population from Stad to Lofoten, and one population from Vesterålen to the Russian border. The colonies at Froan in Sør-Trøndelag are the largest grey seal colonies along the Norwegian coast, however there are also several colonies located along the coast of Finnmark. Grey seals give birth in December, and the young seals change hair after 3 weeks. Moulting takes place from February to April.

Grey seals have changed the status from *nearly threatened* (NT) (2006) to *least concern* (LC) in the Norwegian Red List of 2010, which means that it is no longer directly threatened (Norwegian Biodiversity Information Centre, 2010).

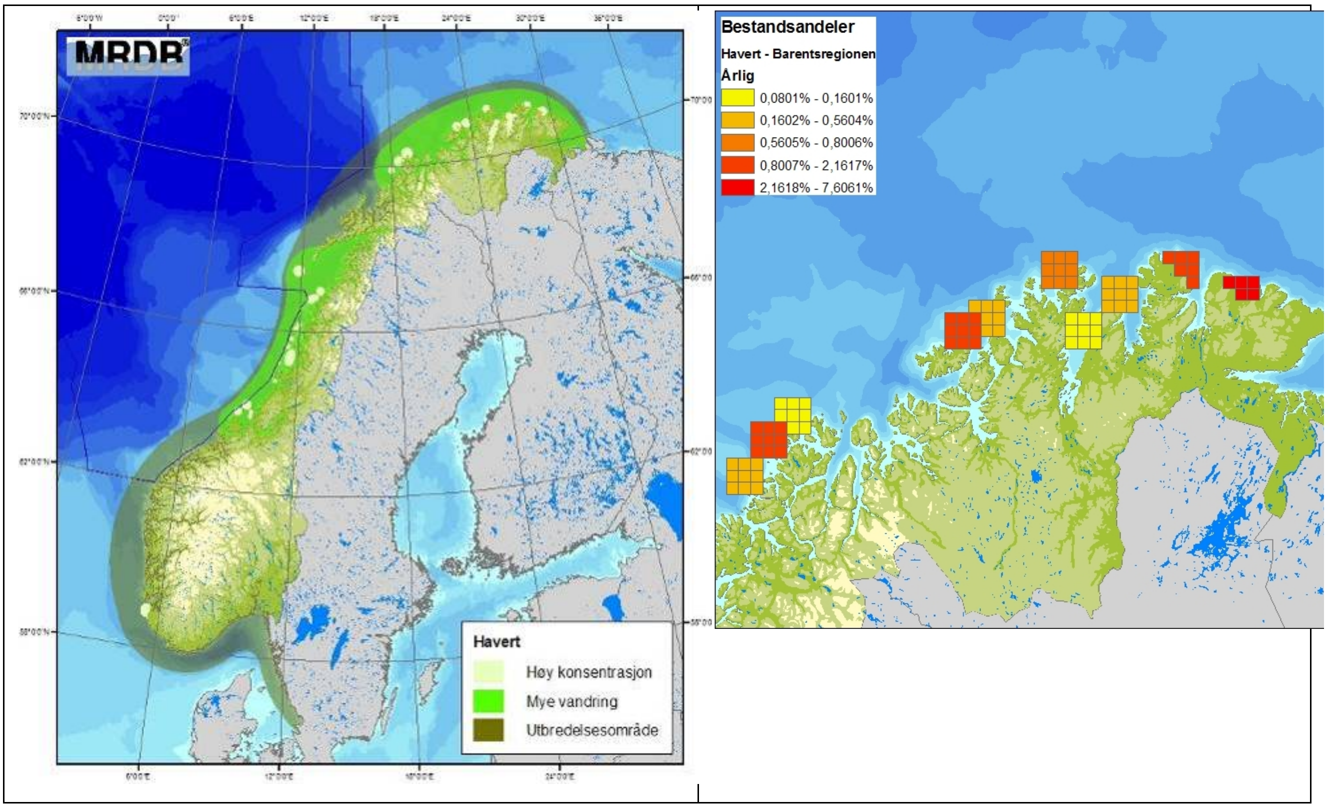


Figure C - 25 *Distribution of grey seals in the Norwegian waters (MRDB, 2010); (DN & HI, 2010). Legend for the left map, from top to bottom: high concentration, many migrations and distribution range. Right hand map: annual average population distribution.*

Both harbour and grey seals are hunted in Norway, and the recommended quotas are set to 5 % of the estimated numbers of individuals (Havforskningsinstituttet, 2015), however the quotas are set higher in areas where there are conflicts between the fisheries and the seals. The seals are also vulnerable to by-catch in fishing gear.

Overall vulnerability of seals / walruses to oil

Oil toxicity depends on its chemical composition, but generally fresh crude is more toxic than refined / weathered oil. Oil will deteriorate over time through evaporation, down-mixing and emulsification. Therefore, oil exposed to vulnerable resources shortly after spillage will generally lead to more acute damage than highly degraded oil.

Toxic effects of oil due to its chemical composition (aromatic hydrocarbons)

- The toxic components of evaporated oil will react with the seals membranes and cause swelling, mucus formation and ulceration. Prolonged exposure may cause permanent damage to the eyes (St.Aubin, 1990); (J.R. Geraci & Smith, 1976).
- Inhalation of volatile hydrocarbons may lead to inflammation and possible pneumonia to seals. Oil components absorbed through the lungs will be transported to the kidneys, liver and brain. Visible effects will likely be behavioural changes (Jensen, 1996); (Hansen, 1985); (St.Aubin, 1990). Brain Damage caused by the inhalation of volatile components is not reversible (Frost & Lowry, 1993).

Intake of oil through ingestion (direct ingestion or contaminated food)

- As seals do not lick their fur clean, they do not ingest toxic components of the oil via that pathway (Jensen, 2008b).
- The general perception is that seals have the ability to consume a small amount of hydrocarbons, as seals have enzymes that can break down most of them. The threshold will vary from species to species, from oil to oil, and depending on the individual's overall fitness. Dangerous intake amount for seals will vary from about 100 ml to several litres (J.R. Geraci & Smith, 1976); (J.R. Geraci & St. Aubin, 1987); (Engelhardt, 1982).
- Oil acts on the intestinal epithelial cells by irritating the stomach / intestines, thereby affecting movement, digestion and absorption (Anon, 1979a, 1979b) and (Anon, 1980a, 1980b, 1980c, 1980d); (Narasimhan & Ganla, 1967); (Rowe, Dollahite, & Camp, 1973).

Stress

It has been shown that oil can cause death to stressed seals. One can assume that seals that already are in a poor condition due to e.g. poor access to food, will be particularly vulnerable to oil, and the entire population could be particularly susceptible to stress caused by oil pollution (J.R. Geraci & Smith, 1976).

Greasing

- Adult seals are primarily dependent on their blubber to keep warm; spillage of oil will therefore not cause threat of freezing to the adult seals. However, pups in their first phase of life (the first few days / week) very vulnerable, as they rely on their fur for insulation (J.R. Geraci & St.Aubin, 1990). Oil contamination will bond the hair together and destroy the insulating air layer in fur. In addition, cold and wind would make pups more vulnerable due to greater heat loss.
- Greasing will lead to limited mobility, especially for younger seals. For example, the flippers can be glued to the body, which would reduce the swimming ability. More sensitive organs like eyes and whiskers are also sensitive (J.R. Geraci & St.Aubin, 1990); (St.Aubin, 1990); (Engelhardt, 1987).

Jenssen (Jensen, 2008b) indicates that the grey seal mothers would try to wash the pups that are contaminated, which then would interfere with lactation and leads to lower weight at weaning than normal.

Biology (behavioural / demographic / physiology)

- Direct observations during previous oil spills indicate that grey seals, harbour seals and ringed seals are not actively avoiding oil (Spooner 1967; St. Aubin 1990; Geraci and Smith 1976).
- Differences in habitat utilization will also make a difference in how an individual is exposed to oil. Especially young seals will prefer shallow water instead of deep water, where oil can accumulate in large concentrations.
- Seals have great energy needs. 5 % of body weight per day, making the seals vulnerable both in the short and long term. If energy needs are not being met, this could lead to starvation and impaired reproduction.
- Seals "strategy" of late maturation, few pups per brood and high survival of mature individuals causes that increased mortality among the sexually mature individuals will have far more serious consequences for populations than an increased mortality within the young individuals.

Otter

The Otter has been protected in Norway since 1982. It is estimated that over 25% of the European population are found in Norway (Brude et al., 2003). Map of otter habitat along the Norwegian coast is shown in Figure C - 26. The Norwegian population is assumed increasing or at least stable. In 1990 it was estimated to 9000-11 000 individuals; in 1995 it was estimated to 17 000-21 000 individuals. Assuming that the growth trend is correct the population to date would be above 30 000 individuals. In particular, populations in central and northern Norway that seems pretty strong, otter are believed to have a continuous distribution in coastal areas from Sør-Trøndelag and northwards (Jensen, 2008a).

Otter is internationally considered as *endangered* in the Red List, and is protected by several international conventions. On the Norwegian Red List, the otter is placed in the category *vulnerable* (VU) (Norwegian Biodiversity Information Centre, 2010).

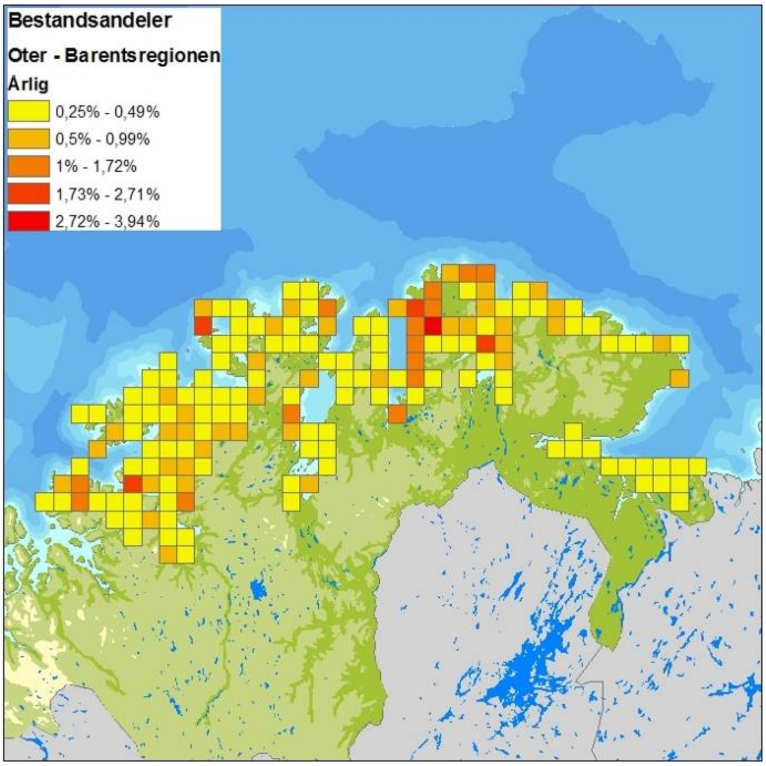


Figure C - 26 *Distribution of otter in the Barents Sea region (MRDB, 2010).*

Overall vulnerability of sea otter to oil

<u>Toxic effects of oil due to chemical composition (aromatic hydrocarbons)</u>

- Pulmonary emphysema was registered as one of the most common causes of death after the Exxon Valdez-accident in 1989, caused by a chemical reaction between the oil components and the otter's lungs. The otters died of the respiratory effects following (Jensen, 2008a).

<u>Intake of oil through ingestion (direct ingestion or contaminated food)</u>

- Otters may consume oil directly through food and or indirectly from oil polluted fur. In particular mussels, which are the main source of food for young animals accumulate hydrocarbons. Oil consumed and digested will affect organs such as kidneys, liver and brain. After Exxon Valdez it became clear that swallowed oil led to bleeding ulcers, which was the primary cause of death. Liver- necrosis was also observed. The oil volume assumed potentially lethal for otters varies, but is estimated to 0.2-0.9 litres (J.R. Geraci & St. Aubin, 1987).

Greasing

- Otters are particularly vulnerable to greasing as they are dependent on their fur for heat. Greasing of oil will drastically reduce the isolation capacity of the fur. This may cause several consequences, from acute death to more chronic conditions (Heggberget & Moseid, 1989).
- Oil polluted otters may seek shelter on land to prevent heat loss, but risk starving to death due to limited access to food (Jensen, 2008a).
- Several of the affected otters that did not die acutely after the Exxon Valdez accident probably suffered long-term injuries, or death caused by the greasing (Lipscomb, Harris, Rebar, Ballachey, & Haebler, 1994).

Whales

The most common coastal whale species in the Barents Sea is the killer whale, while the most common pelagic species includes the baleen whales common minke whale, humpback whale, fin whale and the toothed whales white-beaked dolphin and Atlantic white-sided dolphin. The most common species connected to the ice edge is the narwhale, bowhead whale and white whale. The narwhale is classified as threatened (T), the bowhead whale is classified as critically threatened (CT) and white whale is classified as vulnerable (V) according to the Norwegian Red List (Norwegian Biodiversity Information Centre, 2010).

The distribution patterns of some of the important whale species in Barents Sea are shown in Figure C - 27 and Figure C - 28.

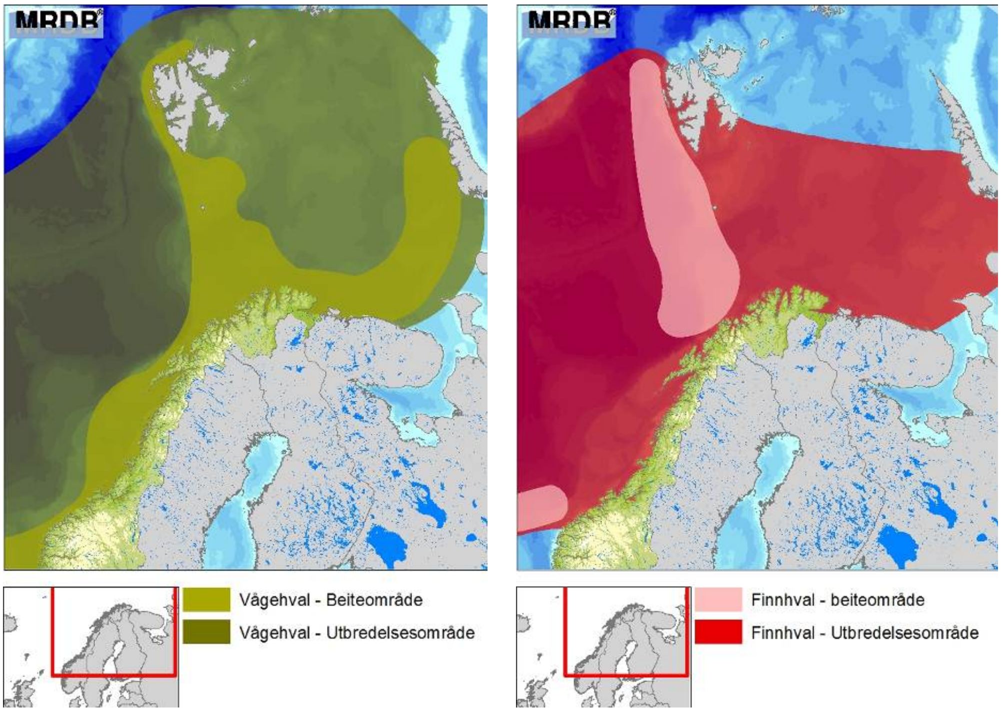


Figure C - 27 *Foraging areas and distribution pattern of common minke whale (left) and fin whale. (right).*

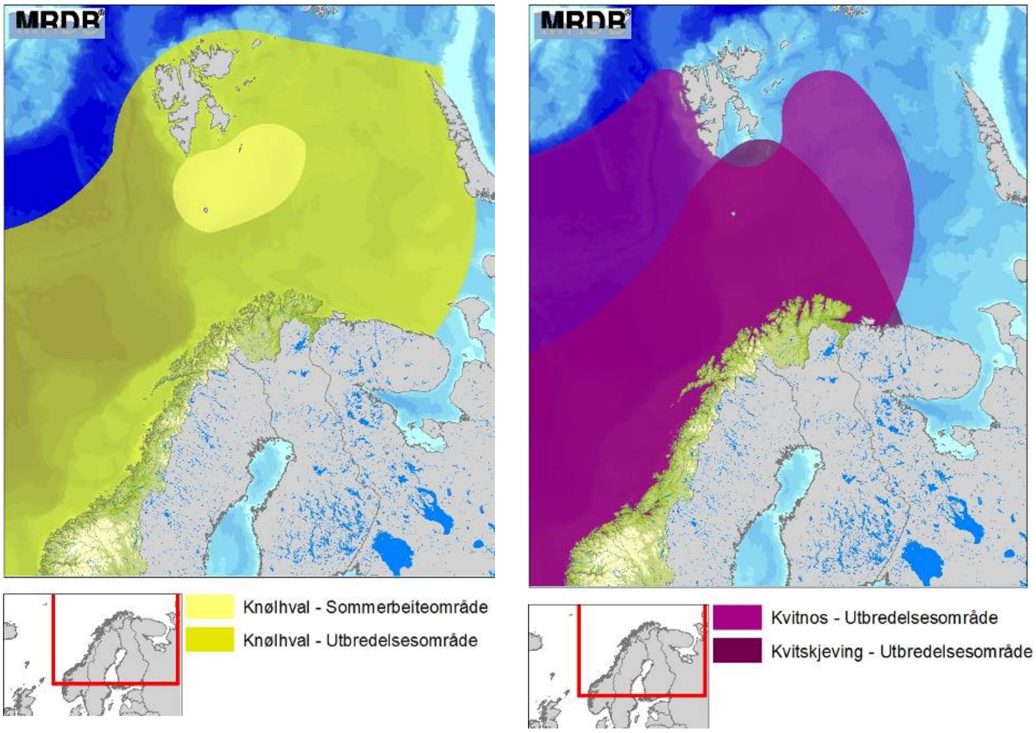


Figure C - 28 *Foraging areas and distribution pattern of humpback whale (left) and the distribution patterns of white-beaked dolphin and Atlantic white-sided dolphin.*

Polar bear

The polar bear is the largest of all bear species in the world. It is classified as a marine mammal, and many of its body characteristics are adapted for cold temperatures, for moving across snow, ice, and open water, and for hunting seals (primarily ringed seal, bearded seal and harp seal) which make up most of its diet. Although most polar bears are born on land, they spend most of their time at sea. Polar bears hunt their preferred food of seals from the edge of sea ice, often living off fat reserves when no sea ice is present, but may also seek food onshore, mainly eggs, seabirds and rein deer cadavers. The polar bear may fast for more than half a year.

The polar bear mates in April/May, but the fertilized egg remains in a suspended state until August or September, only to continue maturation when the pregnant female has dug a maternity den. In the den, she enters a dormant state similar to hibernation. The cubs (on average two) are born in November-February, and the family stays in the den until mid-February to mid-April, and the cubs stay with their mother for two years. Besides from families with cubs the polar bears are solitary hunters wandering alone. The bears may live 15-25 years.

The polar bear is classified as a vulnerable species, with eight of the nineteen polar bear subpopulations in decline. The Barents Sea subpopulation is estimated to 2300-4100 animals (Artsdatabanken, 2010). About half of these are found in the areas surrounding Svalbard for most part of the year. As part of the impact assessment for petroleum exploration in the area in the Barents Sea formerly known as the *Grey Zone,* the Norwegian Polar Institute reported the presences of polar bears based on data for marked bears in the period 1967-2011 and data from aerial counting (2004) (Norsk Polarinstitutt, 2012), see Figure C - 29 and Figure C - 30. Based on these data the Norwegian Polar Institute has given an expected density of polar bears in different types of habitats; i.e. pack ice and fast ice. The data observations are done in August, but may be valid throughout the year. In the pack ice of the Russian territory the observed density is somewhere in the range 1.3-3 bears per 100 km^2, while in the Norwegian territory 0.2-0.6 bears per 100 km^2.

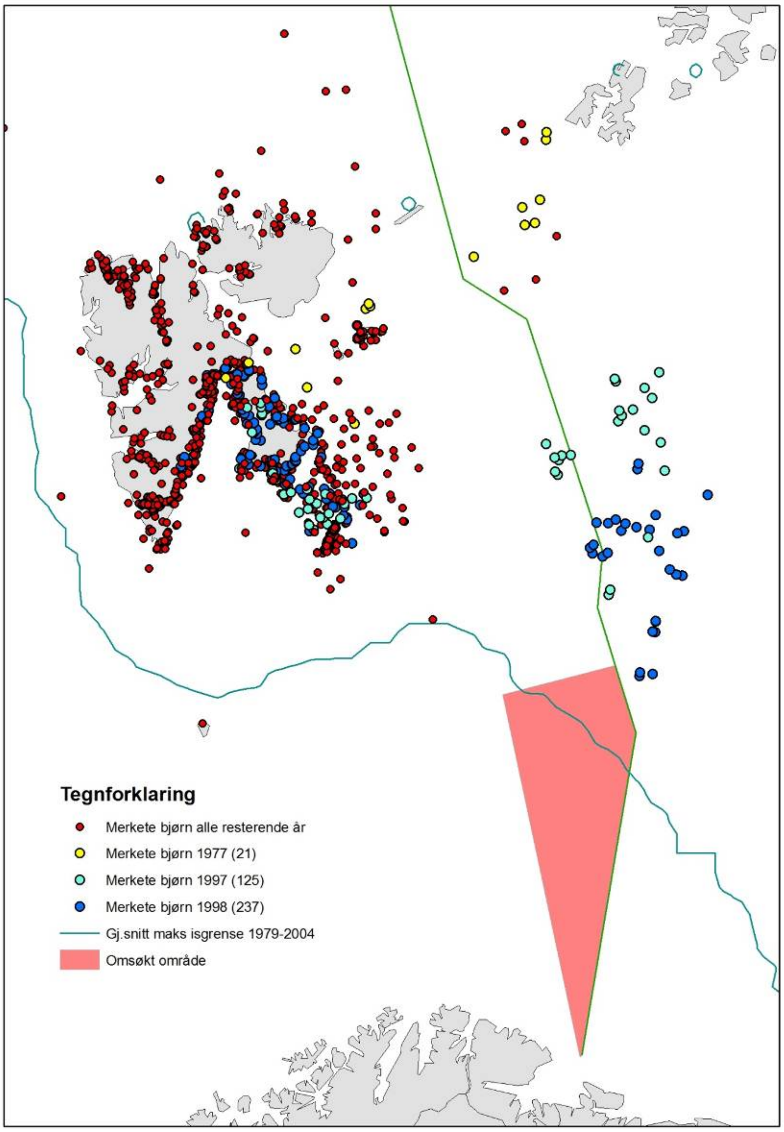


Figure C - 29 *Presence of polar bears in the Barents Sea and Svalbard area. Yellow, turquice and blue dots indicates marked bears in 1977, 1997 and 1998 respectively, while red dots indicated marked bears in the remaing years studies, based on data from 1967-2011 (NP 2012).*

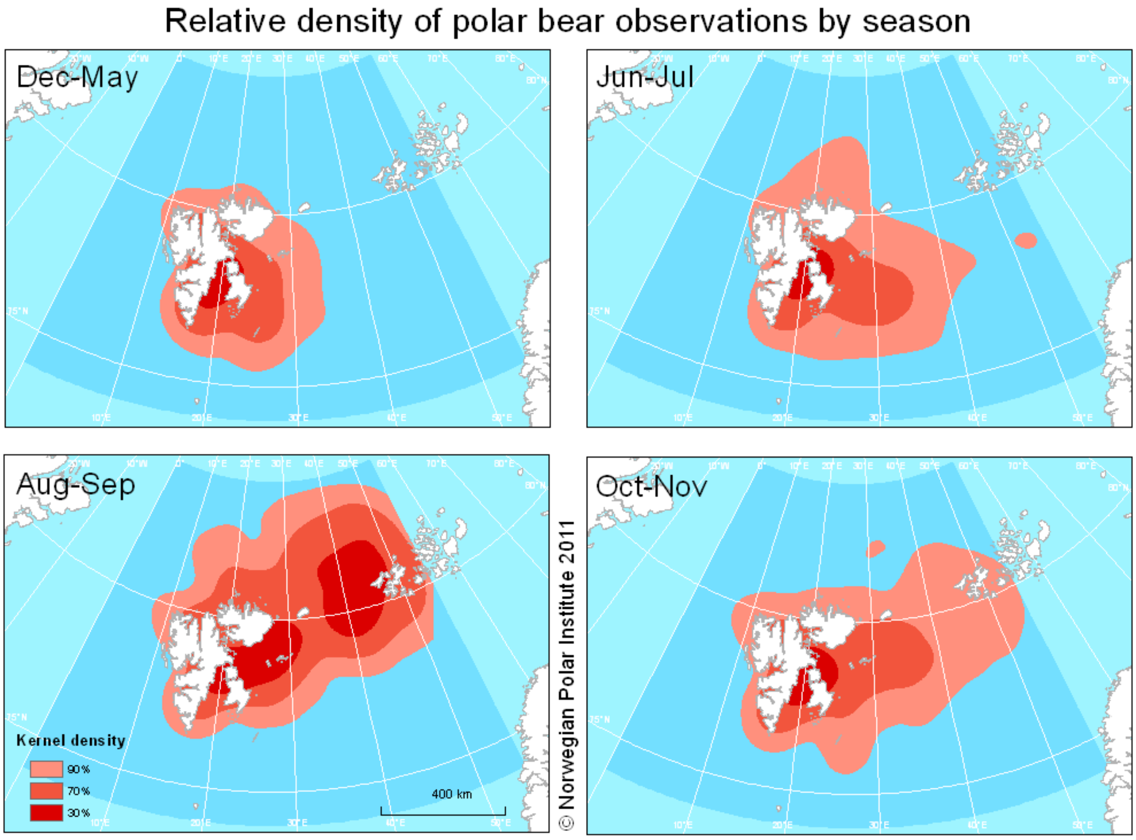


Figure C - 30 *Seasonal presence and relative distribution of polar bears in the Barents Sea/Svalbard are, based on data from marked bears (1967-2011) and air counting (2004) (NP 2012).*

Overall vulnerability of polar bears to oil

Polar bears are known not to avoid an oil spill, but rater seek it out due to curiosity (Derocher, 1996). The polar bears are vulnerable to oiling of the fur disrupting the isolation. It may also ingest the oil while cleaning the fur or eating contaminated pray.

Studies of polar bears in captivity has suggested that oiling of the fur causes ingestion of oil which then again affects the thermo regulation and metabolism negatively (Øritsland, 1981). Oil ingestion may cause behavioral changes and reduce the food intake, as well as dehydration, anemia and kidney failure. It is also proved that the oiling may cause skin irritation and hair loss both under experimental and natural conditions. The polar bear is particularly vulnerable to oil pollution as it is dependent on the fur for insulation, compared to seals dependent on blubber (J.R. Geraci & St.Aubin, 1990).

Activities connected to the clean-up operations may in addition cause disturbance of the dens leading to the death of cups that are left by their mother.

As the polar bears mainly live in solitary most effects of oil pollution are expected on an individual level, however, spills affecting the ice edge in periods of higher concentrations of bears may cause effects on a population level.

Coastal habitats

In the present ERA, a damage-based analysis was conducted for coastal habitats, following the ERA methodology (see Appendix A).

The coastal sensitivity to oil is calculated on the basis of substrate type, habitat and exposure to wind, waves and tide. Vulnerability index V1-V3 is used to describe the coastal habitats vulnerability, where V3 is the most vulnerable. This index is based on the principle that a coastal habitat is vulnerable to oil depending on the type of substrate and the type of flora / fauna within the habitat. This is a standard approach for the ERA methodology. Coastal habitat analysis is carried out with a 10 x 10 km grid resolution. The natural exposure time of oil on the shoreline is significantly lower in exposed areas than in protected areas. Sheltered tidal flats and sheltered rocky shore areas are generally most vulnerable because of their poor self-cleaning ability.

Figure C - 31 shows the percentage (%) of coast classified with vulnerability 1, 2 and 3 of each 10 x 10 km square along the northern Norwegian coastline. The land areas at Svalbard are given vulnerability index 3.

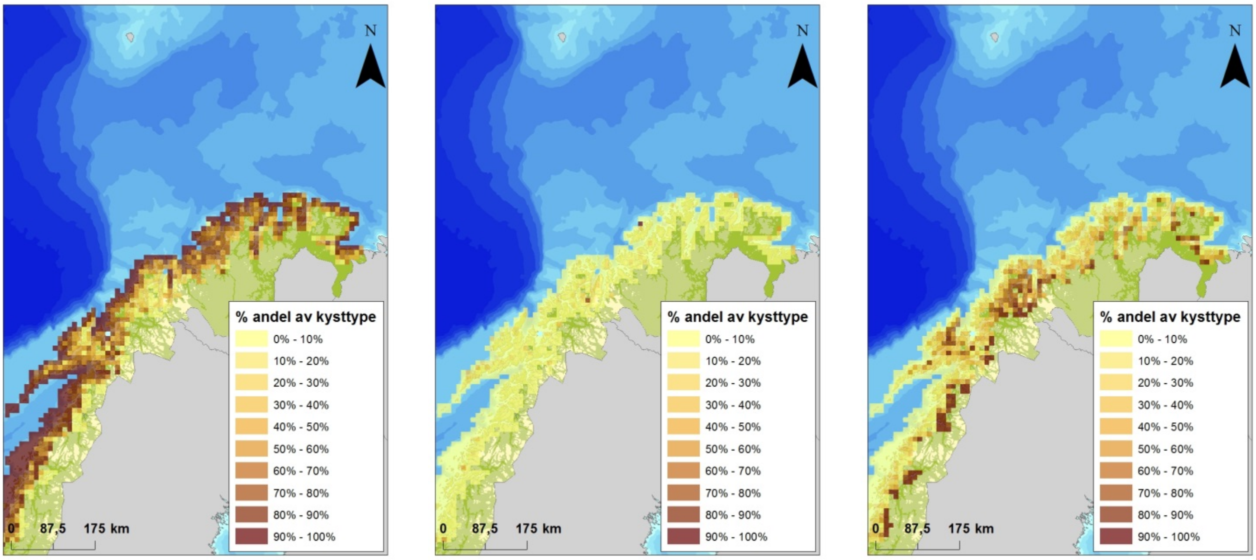


Figure C - 31 *Percentage (%) of coastal habitat with vulnerability 1 (left), 2 (middle) or 3 (right) (3 indicates the highest vulnerability, and 1 indicating the lowest vulnerability) per 10x10 km grid cell along the coast of Norway.*

Fish

The eggs and larvae are the stages most sensitive to oil pollution while fry and adult fish to a lesser degree are vulnerable (SFT & DN, 2000). Thus the areas closest to the spawning areas are the areas with highest potential for damage (RC Consultants & NINA, 1999). The species spawning concentrated in time and space are most vulnerable to acute oil spills.

The most important spawning areas for Norwegian spring-spawning herring and Northeast-Arctic cod are located along the Norwegian Continental Shelf, between 62 ºN and 70 ºN (Stenevik, Huse, & Svendsen, 2005).

Herring and cod mainly spawn in the period from February to April. The pelagic eggs are then transported north towards the nursery areas in the Barents Sea and spread over large areas.

Herring (*Clupea harengus*)

Norwegian spring-spawning herring becomes sexually mature at 3-5 years of age: the maturing age depend on the size of the herring population (less herring, less competition hence high somatic growth). The herring spawn in whirlpools over bank areas along the Norwegian coast mainly from March to April (Sætre, 1999). In the 1980's, 90 % of the spawning stock was situated in a limited area off the Møre coast between 62° and 63°30' N. More recently, the spawning areas have been extended northwards. The oldest and largest fish, which also have the greatest spawning potential, have a tendency to wander further south and to the spawning areas farthest off the coast. Herring spawning for the first time spawn one additional time later in the season. The herring spawn on 40-150 meters depth where the eggs are fixed to the seabed and develop until approximately 3 weeks prior to the hatching. The spawning areas are banks working as retention areas, where the larvae only move within a limited area the first two or three weeks. These areas also have weaker vertical layers than surrounding areas which gives a good access to nutrients for the larvae. The larvae start feeding on nauplia of *Calanus finmarchicus* from five days of age. The larvae drift northwards with the coastal currents. The growth rate and survival vary largely between years, which in turn have an impact on seabird populations such as puffin.

Cod (*Gadhus morhua*)

The cod spawn pelagic and wander against the currents from the Barents Sea along the Norwegian coast to the spawning areas from Møre in the south to Sørøya in western Finnmark. The spawning starts in March and lasts to the beginning of May. In the Lofoten area, the spawning peak is in the first week of April. The most intensively used spawning site is the Lofoten area, especially Vestfjorden, Røst, Røstbanken and Vesterålen. The male fish stays at the spawning banks relatively stationary, whereas the female fish makes local wanderings to and from the spawning banks between each spawning with a gap of 2-4 days. The fish spawn at 50-200 m depth in the transient area between Atlantic water and coastal water (OLF, 2008). The fertilised eggs rise up to the surface and hatch after approximately 15 days (temperature dependent). When the cod larvae hatch, a yolk sac serve as a food-storage in the early phase. The survival of larvae can be disrupted immediately after hatching due to ruptured yolk sacs. When the yolk sac is consumed by the larvae (typically after 7-14 days) it needs to catch nutrients from the water, mainly plankton of a certain size, which in the Norwegian areas mainly consists of nauplia (fry) of *Calanus finmarchicus*. Because the larvae are planktonic, they follow the currents passively and have minimal possibilities to move, and are dependent on the presence of these nauplia to survive. The larvae stay between 0 and 200 m depth, with the highest concentrations at 10-20 m depth. The larvae go through a metamorphosis by approximately 12 mm length while they are brought into the Barents Sea by the currents. The movements of larvae/fry are rather tug-wise than steady, as they are caught in retention areas when passing banks, for instance at Tromsøflaket.

The evaluations of possible consequences for the survival of cod and herring after an oil spill are based on model data from the Institute of Marine Research (IMR) for the period March-September 2008-2009. The datasets are generated with IMR's operational high-resolution larvae drift model (see Figure C - 32). The data represent a long time series for larvae distribution and drift of eggs and larvae from the spawning areas into the Barents Sea. The datasets was first used in the work with updating the management plan for the Norwegian Sea (DNV & SINTEF, 2010). It should be noted that the yearly variation between the different distributions is relatively high and that in the analyses data from 10 days intervals for each individual year have been utilized.

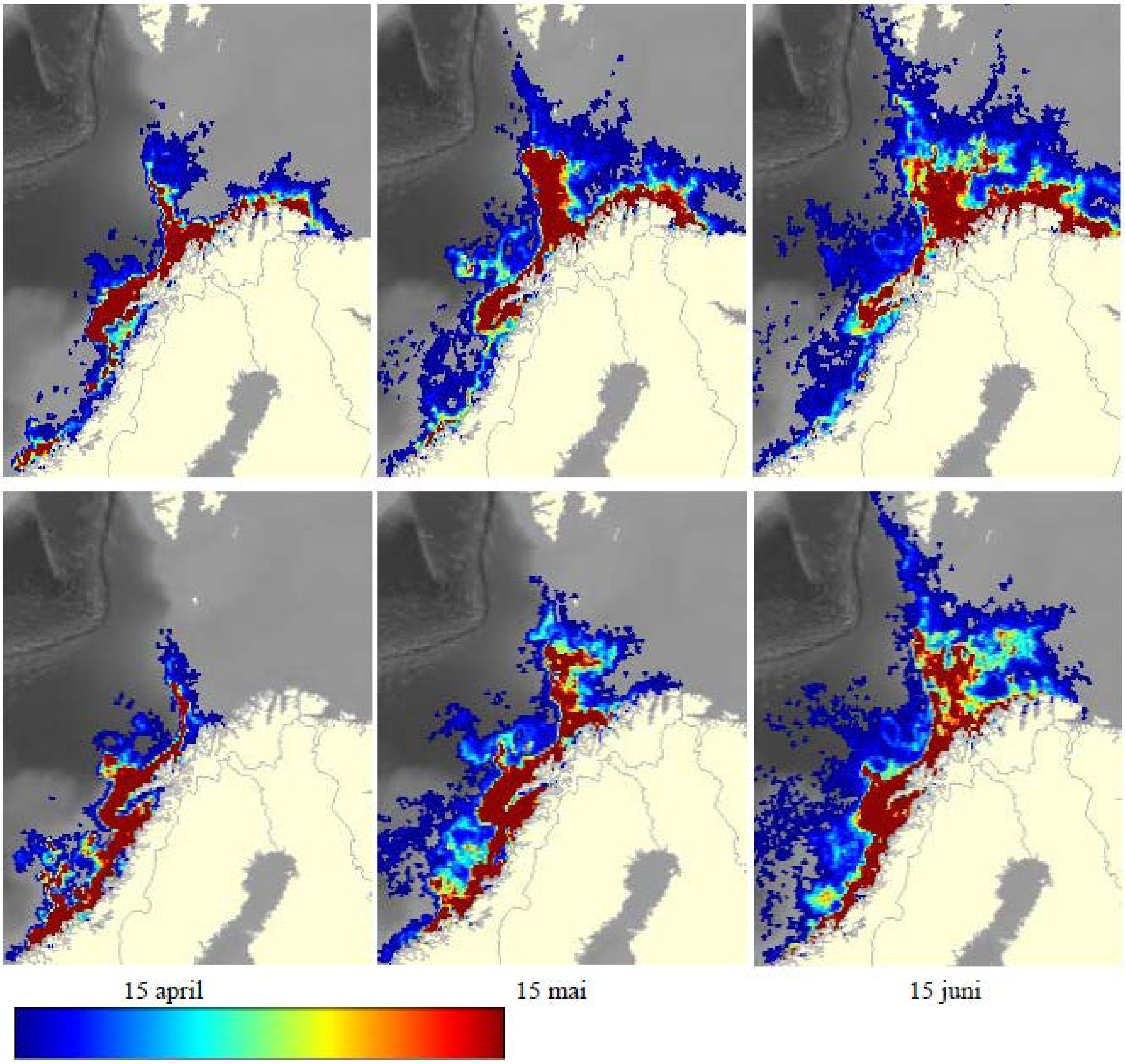


Figure C - 32 *Distribution of larvae of cod (upper figures) and herring (lower figures) in 2009, at different time of the year; 15th of April (left), 15th of May and 15th of June (right) (Vikebø et al., 2009).*

Polar Cod (*Boreogadus saida*)

The polar cod is a pelagic/semi pelagic fish species. It is a key species of Barents Sea ecosystem, as it is an important source of food for other fish, seals, whales and birds. It feeds mainly on zooplankton. The stock of polar cod in the Barents Sea is probably between 1.5 and 2.0 million tonnes.

The distribution area and the size of the stock are mapped by acoustic methods during an annual ecosystem survey in the autumn. It is not clear whether polar cod found further north and east belong to the Barents Sea stock, which seems to spawn in two separate areas: east of the Spitsbergen Archipelago; and in the south-eastern regions of the Barents Sea, see Figure C - 33. The spawning takes place in the winter under the ice. It takes a long time before the eggs are hatched, but in the late summer, early autumn the larvae is spread out in the entire eastern and northern part of the ocean, as well as in the areas surrounding Svalbard.

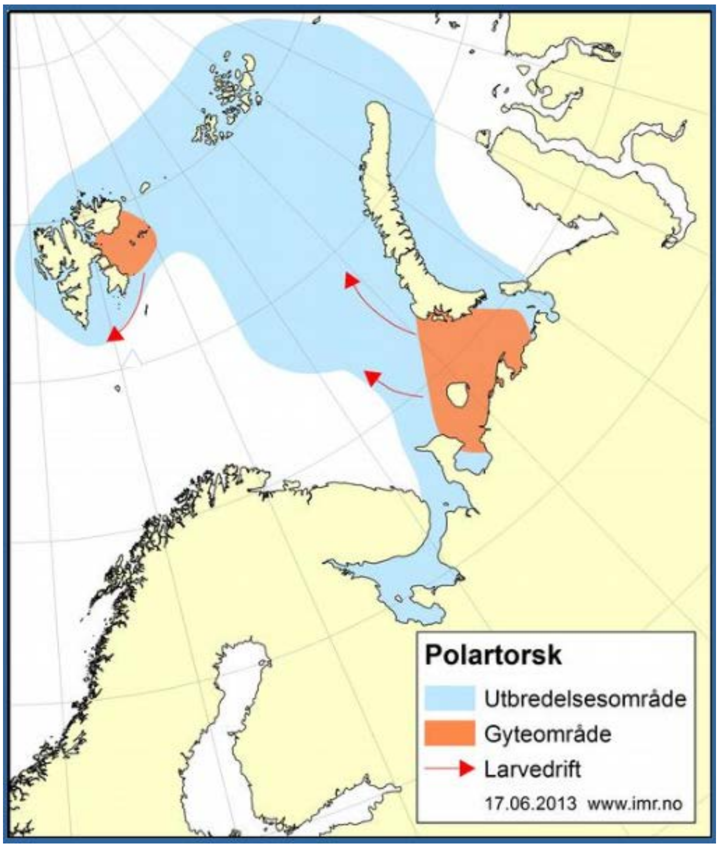


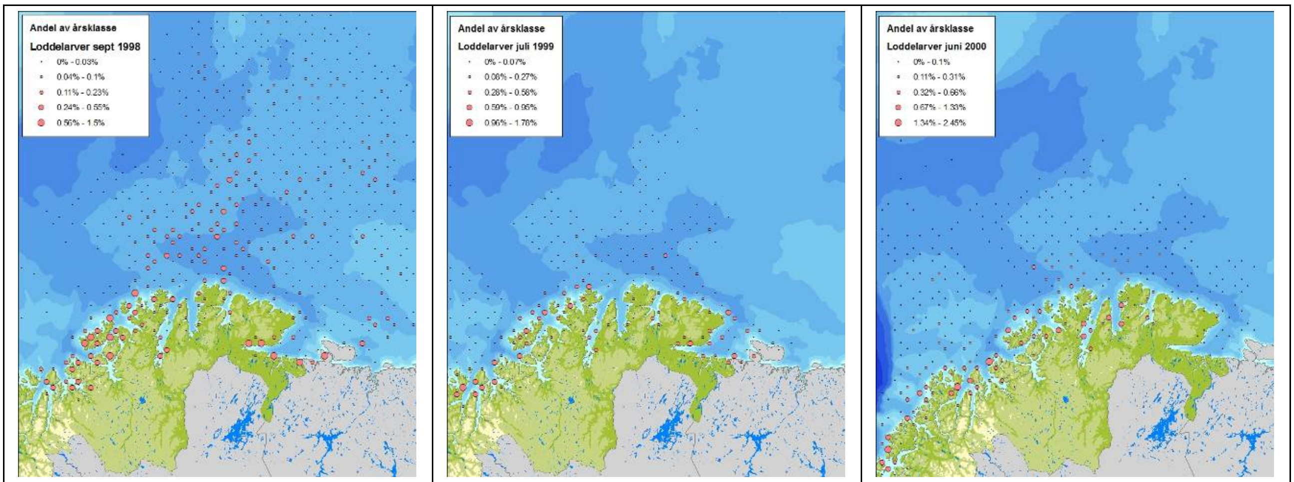
Figure C - 33 *Map of distribution of Polar Cod; orange illustrating the spawning areas, red arrows illustrating the larvae drift and blue area illustrating the general distribution (Havforskningsinstituttet, 2014).*

Capelin (*Mallotus villosus*)

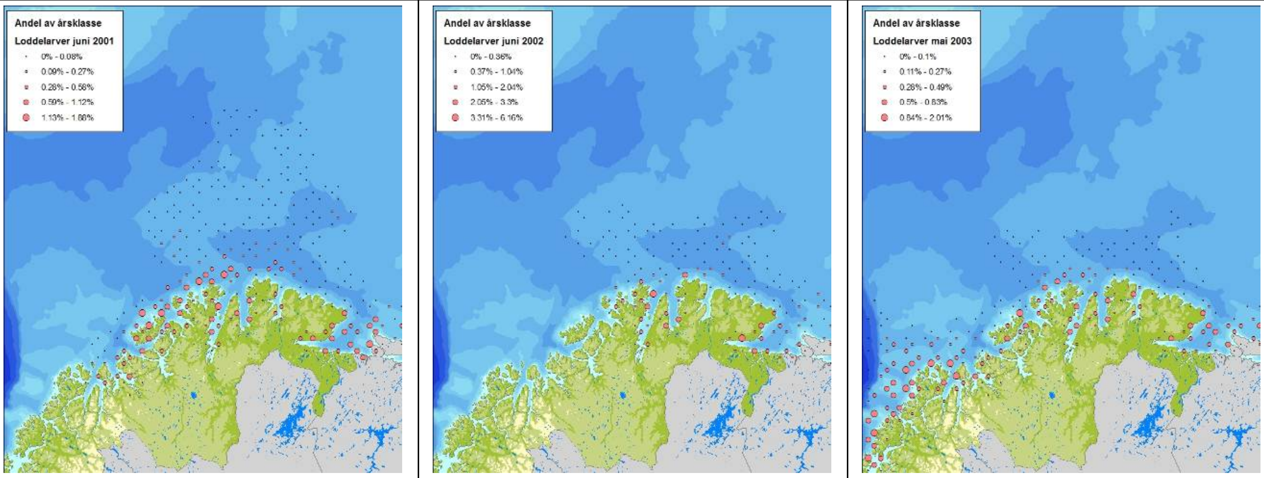
Capelin is an important species in the Barents Sea transforming a lot of the secondary production to fish proteins, as well as being an essential food source for other fish species, seabirds and marine mammals. Spawning occurs in the Barents Sea, inside an area that stretch from Vesterålen to east of the Murmansk fjord, often with an eastern or western concentrated spawning centre. Capelin covers its eggs in gravel banks at 30 to 50 m depth. Eggs and egg yolk larvae evolve in the gravel, and swim out when the conditions are good.

Capelin larvae drift with the current in the upper part of the water masses, and the direction of the drifting is related to where the spawning has taken place. In years when spawning carried out in the western part (Troms and Vest-Finnmark) of the sea, the larvae will be transported along the Egga-shelf towards the areas west of Spitzbergen. In years when the spawning is carried out in the eastern part (Midt-Finnmark to Murmansk) of the sea, the larvae will be found in the north-eastern part of the Barents Sea. Temperature and access to nutrients in the Barents Sea is critical conditions for the growth of the larva and for the metamorphosis the first summer. Capelin overwinters as larvae or so called “glass- capelin”. Capelin has a north-south feeding pattern as the Polar front moves.

Capelins usually spawn at age 3-4 years, and since capelin is in the salmon family it is common that most of the fish die after first time spawning. The short life cycle makes the capelin vulnerable for external influences. In a year with large herring classes that feed on the capelin larvae, the next 2- 3 years will have a low recruitment of capelin which again will lead to a dramatic decline in the population for capelin because of the short life cycle. An overview of the distribution of capelin larvae at different times in the period from 1998-2003 is given in Figure C - 34.



September 1998 (day 254) **July 1999 (day 193)** **June 2000 (day 173)**



June 2001 (day 165) **June 2002 (day 158)** **May (day 134)**

Figure C - 34 *Distribution of different capelin larvae year-classes within the data set period. 1998 – 2003. in the Barents Sea (Eriksen, Gjøsæter, Bakkeplass, & Alvarez, 2006).*

Effects and vulnerability of fish to oil

Fish eggs and larvae is the most vulnerable life stages related to oil exposure. Juvenile and adult fish may avoid water masses with high concentrations of hydrocarbons, and it is rarely registered high numbers of dead fish after an oil spill (Hjermann et al., 2007). However, after the Amoco Cadiz accident large numbers of dead adult fish was reported. The accident happened close to shore and most of the oil emulsified.

It is reason to believe that the simple structure of the Arctic ecosystem makes it generally more vulnerable to external influence, making it more vulnerable to changes in key species. Fish stocks such as cod and herring are probably at their climatic limit due to the special environmental conditions in the Barents Sea, and they have a short and intense spawning period in restricted to limited areas (Hillebrand, 2004), (Hamre, 1994). The effects of an oil spill in these areas may be critical as the spawning product is concentrated.

Areas of particularly environmental sensitivity (APES)

Areas of particular environmental sensitivity (APES, in norwegian: SVO) are defined through the work with the management plan for the Lofoten and Barents Sea (HI, 2010). The areas are shown in Figure C - 35. The areas includes the Polar front, a 50 km coastal belt along the coast of Finnmark and the ice edge. The APES are defined based on the following criterias:

- Areas with large production and concentration of species
- Areas with large occurences of threatened or vulnerable nature
- Key areas for norwegian species of special responsibility
- Areas with national or international important populatoins year round or during periods of the year.

The Polar front and the ice edge are areas of high biological production. The areas have been evaluated in the environmental risk calculations based on the assumptions that large concentration of seabirds and other natural resources will gather in these areas (see sections 5.1.55.1.6 and 5.1.6).

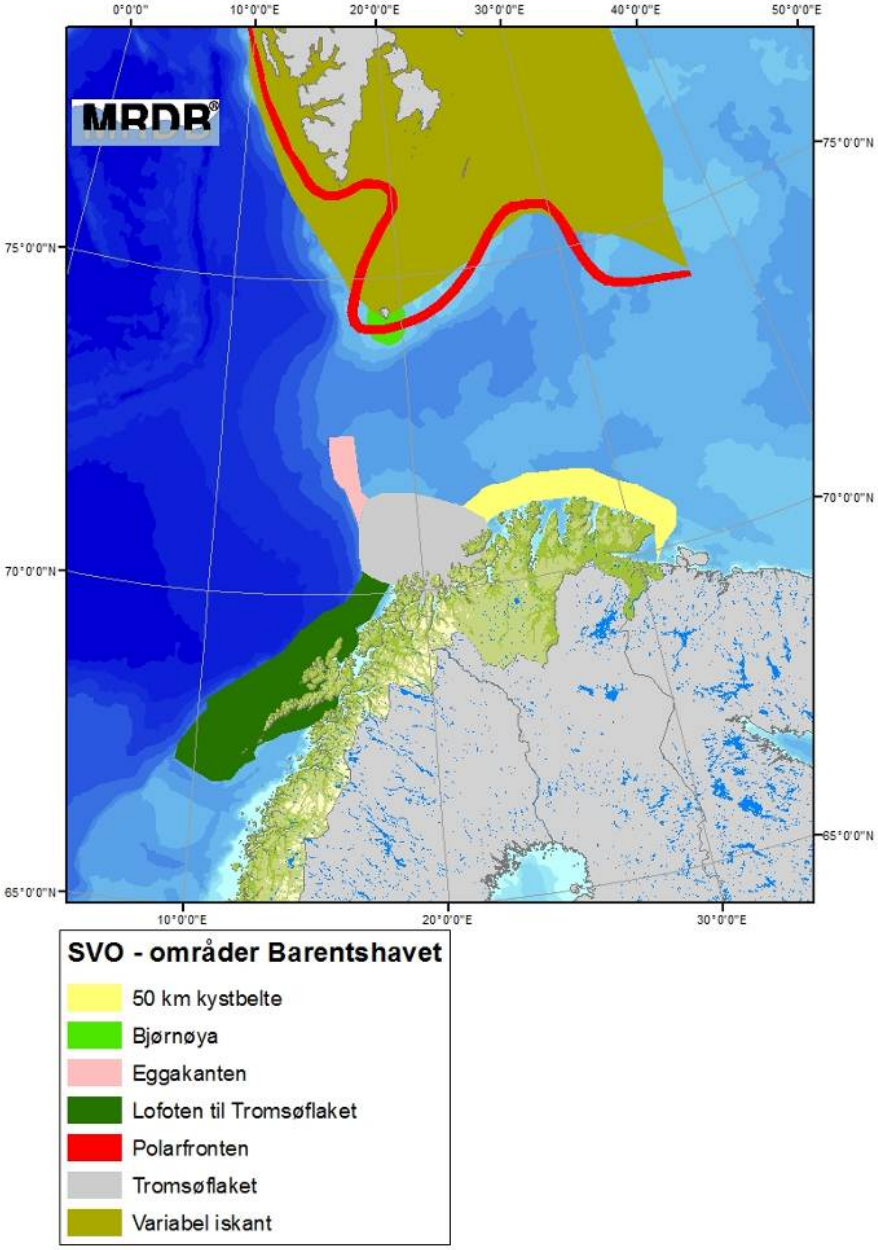


Figure C - 35 *Areas of particular environmental sensitivity in the Barents Sea (HI, 2010).*

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